DEVELOPMENT AND APPLICATION OF A WEB-BASED KANBAN SYSTEM

KHOO BOON BING

(Bachelor of Engineering (Hons.), NUS)

A THESIS SUBMITTED

FOR THE DEGREE OF MASTER OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL UNIVERSITY OF SINGAPORE

2004

ACKNOWLEDGEMENT

The author would like to express his sincere appreciation and gratitude to the following people who have shared their invaluable experience and given their guidance and support during this research project:

1. A/P Lee Kim Seng, main project supervisor, for his continual support and sharing his experiences throughout the project as well as an approachable mentor.

2. A/P Wong Yoke San, project co-supervisor, for his continual guidance as well as providing invaluable advice and recommendations throughout the project.

3. Mr Kenneth Soh, MNC* director, for his support to carry out this collaboration project in the company.

4. Mr Andy Kwa, MNC senior supervisor, for his help and guidance throughout the project implementation in MNC.

5. Mr Low Chin Chun, MNC supply chain manager, for the administrative support and guidance during project implementation.

6. All the friends and colleagues from LCEL & MNC for creating a pleasant learning environment throughout my course.

The author will like to thank National University of Singapore and Department of Mechanical Engineering for awarding the research scholarship and funding the research.

* MNC refers to the multinational company where the case study in this thesis is being carried out. The real name of the company is not revealed for confidentiality

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SUMMARY

Many manufacturing and assembly environments today have adopted the just-in-time (JIT) management philosophy to streamline material flow as well as to attain a lean manufacturing and supply chain system. One of the main techniques employed in JIT management is the Kanban system.

The advent of Internet and Web-based technology in recent years has led to the exploration of opportunities to integrate the Kanban system with these available technologies in order to better manage the manufacturing logistics and supply chain in JIT management. A generic Web-based Kanban system framework has been proposed based on the methodology of the traditional Kanban system. A prototype of the Web-based Kanban using Java 2 Enterprise Edition technology platform has been developed as a software demonstration.

A case study implementation of the proposed Web-based Kanban system has been carried out in an assembly plant. In addition to the proposed modules and functionality of the Web-based Kanban, several customized features are also added to the implementation model to enhance its use within the company. The Web-based Kanban implementation yielded positive results, including inventory reduction, elimination of non-value added activities and provided other significant cost savings to the company.

The successful adoption and implementation of the Web-based Kanban in the company case study has opened the door to incorporate further enhancements and functionalities to the currently proposed system. It also serves as a justification model for other manufacturing companies that plan to adopt a similar approach to Web-based JIT manufacturing.

Keywords: Kanban, Just-In-Time, Web-based manufacturing, Java

NOMENCLATURE

JIT	Just-in-time
MRP	Materials Requirement Planning
WIP	Work-in-process
CONWIP	Constant Work-in-process
LAN	Local Area Network
IP	Internet Protocol
HTTP	Hypertext Transfer Protocol
BOM	Bill of Materials
MRP II	Manufacturing Resource Planning
WWW	World Wide Web
HTML	Hypertext Markup Language
CGI	Common Gateway Interface
PHP	PHP Hypertext Processor
OOP	Object Oriented Programming
ASP	Active Server Pages
JSP	Java Server Pages
J2EE	Java 2 Enterprise Edition
SQL	Structured Query Language
ERP	Enterprise Resource Planning
VMI	Vendor Managed Inventory
AI	Artificial Intelligence

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Chapter 1: Introduction

1.1 Web-based Kanban & Just-in-Time Manufacturing

The implementation of just-in-time (JIT) manufacturing management system to eliminate waste and non-value adding activities, is an important milestone for manufacturing companies to achieve competitive advantage. Since the introduction of JIT management philosophy in the 1960s (Schniederjans 1993), JIT manufacturing has continued to evolve as an implementation model in many current production practices within companies (Hallihan, Sackett and Williams 1997). A major approach and technique to JIT is the use of the Kanban system adopted by Toyota Motors assembly plant in the 1970s as part of the Toyota Production System (Lu 1985, Monden 1998). The Kanban system functions as a material and inventory control system, and has been developed based on the concept of producing exactly the type and quantity of parts needed at the required time. Such a system inevitably displays the capability to respond to market changes, as well as the reduction of inventories within a repetitive manufacturing system.

In recent years, there is intense competition among manufacturing companies to be responsive to customer's demands that are distributed globally and the shortening of product life cycle are making it more imperative for organizations to better design, integrate and manage their manufacturing system and supply chain (Voss and Clutterbusk 1989). As more of these manufacturing companies try to streamline their operations by adopting the JIT management philosophy, the flow of information and materials within the manufacturing system has become critical factors in achieving competitive advantage. With the advent of the Internet and Intranet era, the ability to quickly transmit information will eventually lead to faster and more effective flow of materials within the manufacturing supply chain, thereby reaping the benefits of reduced manufacturing lead time and cost coupled with improvement in quality and service (Worthington and Boyes 2002). Hence, a Web-based JIT Kanban system model that integrates both the JIT management as well as Internet technology should be a key consideration for a manufacturing company that aims to improve and enhance their manufacturing system and operations. The major advantages of a Web-based Kanban system is the availability of visible and real-time information within the manufacturing operations as well as the flexibility to respond quickly to market changes

1.2 Research Objectives

The objectives of the research project are:

I. To develop a Web-based Kanban system for repetitive assembly manufacturing

II. To develop a Web-based software application to support the Web-based Kanban system model

III. To implement and perform a case study of the Web-based Kanban system model on a manufacturing assembly plant

1.3 Organization of Thesis

Chapter 1 provides an overview and objectives of the research project with a short introduction of the proposed Web-based Kanban and its associated roles and projected benefits to the manufacturing industry.

Chapter 2 gives a literature review on the traditional Kanban system, variations of the Kanban system and a short discussion on the challenges and problems faced by the traditional Kanban system

Chapter 3 describes the proposed Web-based Kanban system and assesses the different Web-based technology platform available to develop the prototype. It also discusses the benefits of the proposed Web-based Kanban system.

Chapter 4 presents a case study implementation of the Web-based Kanban in a company and discusses the results and evaluation of the project implementation.

Chapter 5 concludes the thesis with recommendations for further research.

Chapter 2: Literature Review

2.1 Toyota Production System

The Toyota production system was developed by Toyota Motor Corporation and is being adopted by several Japanese companies in the 1970s (Lu 1985, Monden 1998). The primary goals of the Toyota production system mentioned by Monden are:

- ❑ *Increase profit by reducing cost of production*

Production cost reduction can be achieved through productivity improvement such as better inventory and labour management in manufacturing.

- ❑ *Minimize or eliminate wastes in manufacturing*

Overproduction and excessive resources are some of the wastes generated during manufacturing. This will eventually lead to excessive inventories that create the need for more investment in manpower, equipment and storage space. If the exact type and quantity of products are produced only at the required time within the manufacturing system, the problem of overproduction can be overcome.

- ❑ *Inventory control and quality assurance*

Good inventory control will enable the system to adapt quickly to variation in demand. Quality assurance helps to ensure that every process within the manufacturing system are supplied with only good units thus reducing production cost incurred by the defective products.

In order to fulfill the goals in the aforementioned, the Toyota production system builds upon four major concepts: Just-in-time (JIT), automation, flexible work force and originality/ingenuity. The Kanban system is one of the methods being adopted to maintain the JIT concept in the Toyota production system.

2.2 Just-in-Time Management in Manufacturing

Just-in-time manufacturing is a management philosophy applied in manufacturing to ensure that the right items with the right quality and quantity are in the right place at the right time (Cheng and Podolsky 1996). It seeks to utilize all resources in the most efficient manner by eliminating wastes that do not contribute values for the customers (Gregory and Paul 2000). If JIT can be successfully employed within an organization, the result will be a lean manufacturing environment without excess inventories and storage space required. Ultimately, these excess inventories will translate to cost savings in terms of inventories holding and improved capital turnover for the company.

There are several approaches to JIT in manufacturing. Inventory management, quality control and production planning and scheduling are the major key applications of JIT (Marc 1993). As mentioned in the earlier section, Kanban is one of the commonly used JIT methodologies in production planning and scheduling. Marc (1993) has also highlighted several critical JIT production management principles that the organization should embrace in order to reap the full benefits of JIT. Table 2.1 provides a list and summary of these principles.

Table 2.1 Summary of JIT Production Management Principles

No	Principle	Description
1	Seek uniform daily production scheduling	Minimum variation in production quantities should be fulfilled daily. Load leveling whereby production plan for each product quantities are allowed to be changed monthly but demonstrates no fluctuation each day
2	Seek production scheduling flexibility	A level of production capacity should be established to allow flexibility in meeting minor shifts in customers demand. The operations supporting JIT need to have such flexibility to ensure scheduled production can be adjusted accordingly to match the actual variation in demand.
3	Seek a synchronized pull system	The customer order is the main driving force for a production pull system. The production operations should seek to be synchronized to the customer demand pull. The Kanban system is one that can be used under this requirement.
4	Use automation where practical	Seeks to allocate resources based on rationale economics. JIT operations employs human labour where greater flexibility is required than can be performed economically through automation
5	Seek a focused factory	A limited number of products and production operations should only be dedicated to the factory. A balance should be maintained between the number of production operations and the amount of flexibility in manufacturing a number of similar products sharing production processes.
6	Seek improved flexibility in workers	Use of part-time workers or providing extensive multi skills training for workers.
7	Cut production lot size and setup costs	Reducing inventory ordering lot sizes can drive up setup costs due to increase frequency in production runs. Therefore setup costs have to be reduced through focusing on waste elimination such as employing the five S's of proper arrangement (seiri), orderliness (seiton), cleanliness (seiso), cleanup (seiketsu) and discipline (shitsuke).
8	Allow workers to determine production flow	The production lines will halt WIP inventory at work centers until the worker approves sending it along. This helps to identify the problems that slow the production process.
9	Improve communication and visual control	Visibility management helps to enhance management control and rectifications when the goals of JIT are not met.

As stated under Principle 3 in Table 2.1, the Kanban system is employed to fulfill the requirements of a pull system. Material replenishment in manufacturing can either take the form of a 'pull' system or 'push' system although a hybrid of both systems could exist within the manufacturing supply chain. In a typical 'push' system, the in-process inventories are pushed from a work center to the next after a work order is completed. The use of master schedules and material requirements planning (MRP) to drive production schedules and material flow in the factory are characteristics of a 'push' system (Arnaldo 1989). Such a system relies primarily on demand forecasting and operates independently of customer's actual demand often resulting in excess inventory. Figure 2.1 depicts a simplified push system (MRP) framework (Harold and Paul 1992).

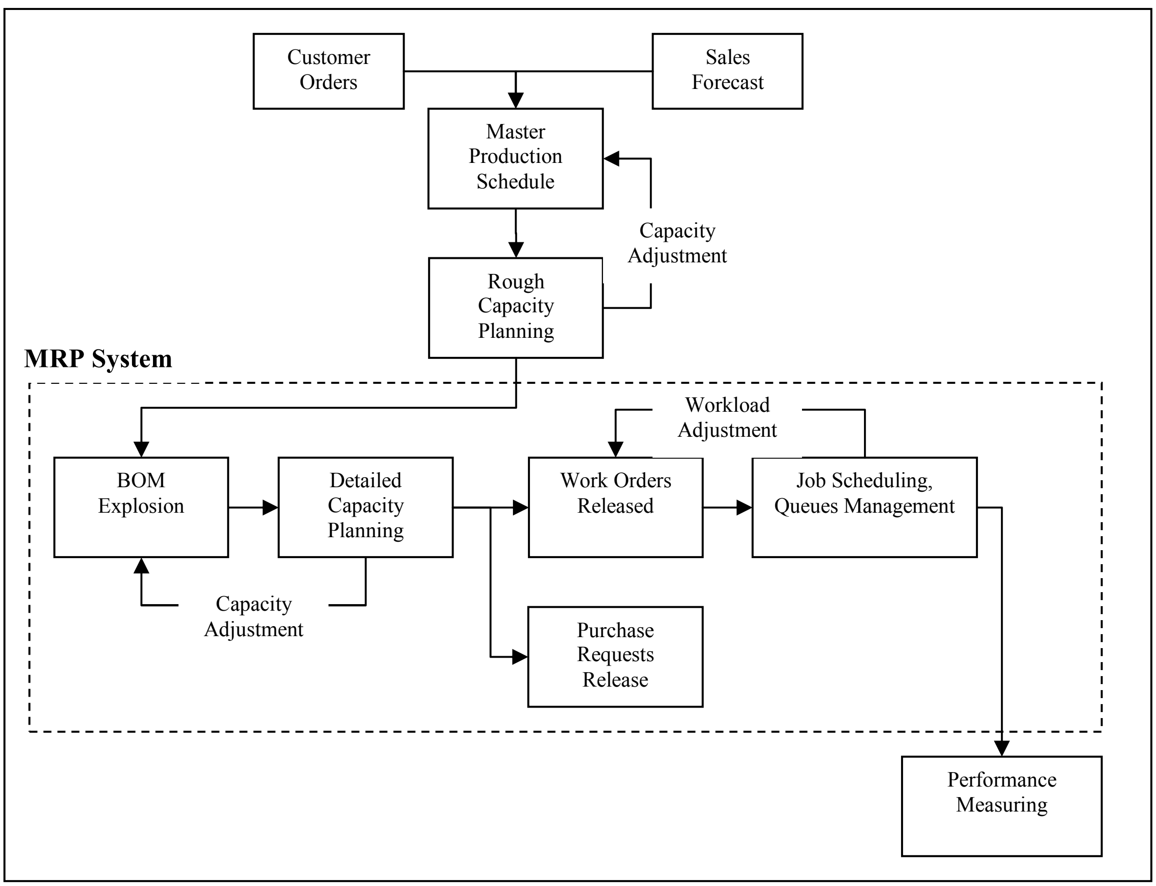


Figure 2.1 A Simplified 'Push' System (MRP) Framework

The 'pull' system on the other hand brings in inventory from the work center only when the subsequent work center makes a material request through a work order. The Kanban system is a common method used in a 'pull' system to move material within the manufacturing supply chain. Parts or materials are requested for by the customers only when needed, and the system is highly sensitive to variation in demands where actual usage rate determines material flow instead of scheduled usage rate (Alan 1992). The result is a reduction in inventory and WIP in the production pipeline. Manufacturing problems, such as quality issues, can then be easily identified and rectified immediately. Figure 2.2 shows a general 'pull' system framework (Harold and Paul 1992).

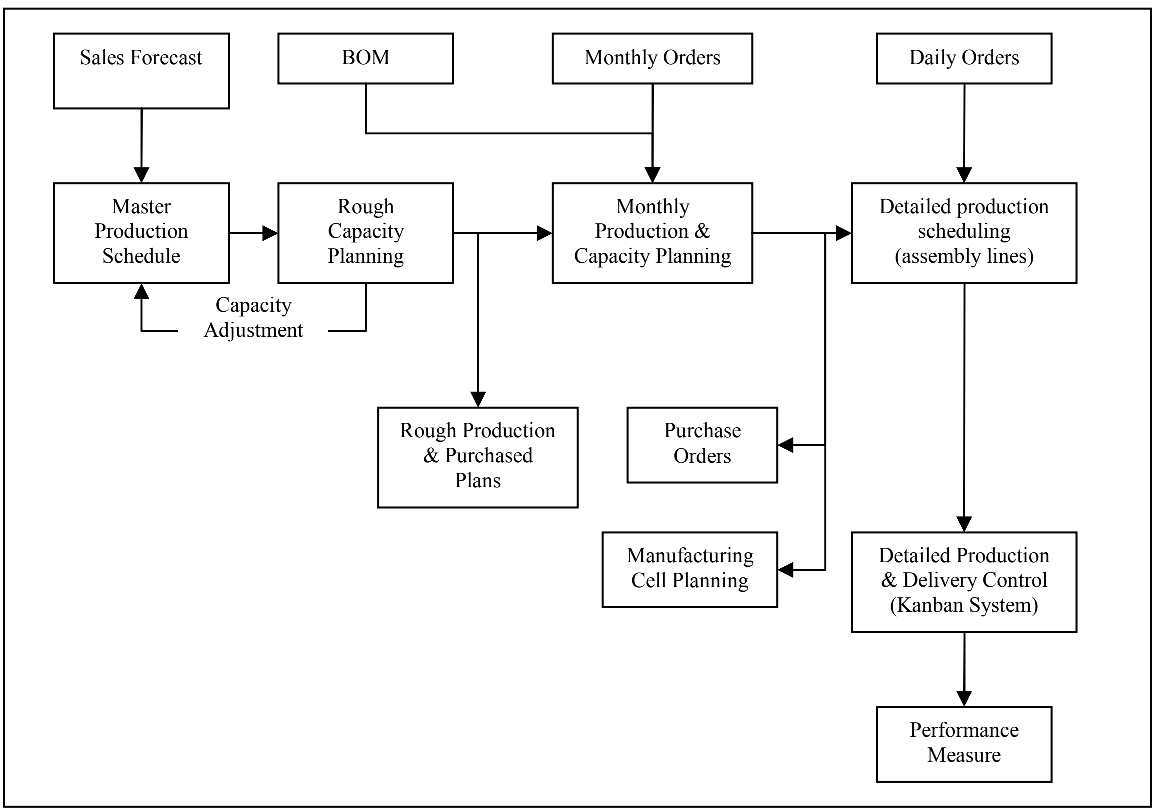


Figure 2.2 A General 'Pull' System Framework

A comparison of both the 'push' system and 'pull' system framework will reveal one major difference, that is, the assembly lines or work centers in a 'pull' system are mainly driven by a detailed production schedule obtained from customer's demands arriving in the form of monthly and daily orders. As observed in Figure 2.2, the pull system also needs to be regulated by the Kanban system at the end of the process flow framework. The Kanban system is a key tool in determining the success of implementing a JIT 'pull' system in manufacturing.

2.3 The Traditional Kanban System

The traditional Kanban system, also know as a dual-card Kanban system, is an information system that controls and regulates the manufacturing of required products in the demanded quantities and time between manufacturing processes as well as collaborating companies, such as suppliers or sub-contractor (Monden 1998). It is a 'pull' process whereby the subsequent stage or assembly line in a manufacturing process will control the flow of materials from the preceding stages. Jin and Schonberger (1988), Esparrago (1988), Mahnesh and Yash (1989), and Huang and Kusiak (1996), detailed description and illustrated the Kanban system model. The key working elements are explained in the following sections.

Kanban is a Japanese word that denotes a 'card'. It is a visual means of providing information to regulate the flow of inventory and materials. The Kanban system works on the principle that the preceding stage in the manufacturing process will only produce the exact quantity of material parts to be drawn by the subsequent stage. This authorization of withdrawal and production of material is carried out through the use of the *kanban. The kanban or card contains details such as the material part number, material name, type and location of the preceding and subsequent process for the material, quantity of material in the container accompanying the kanban and kanban number. Figure 2.3 shows a schematic representation of a general kanban.

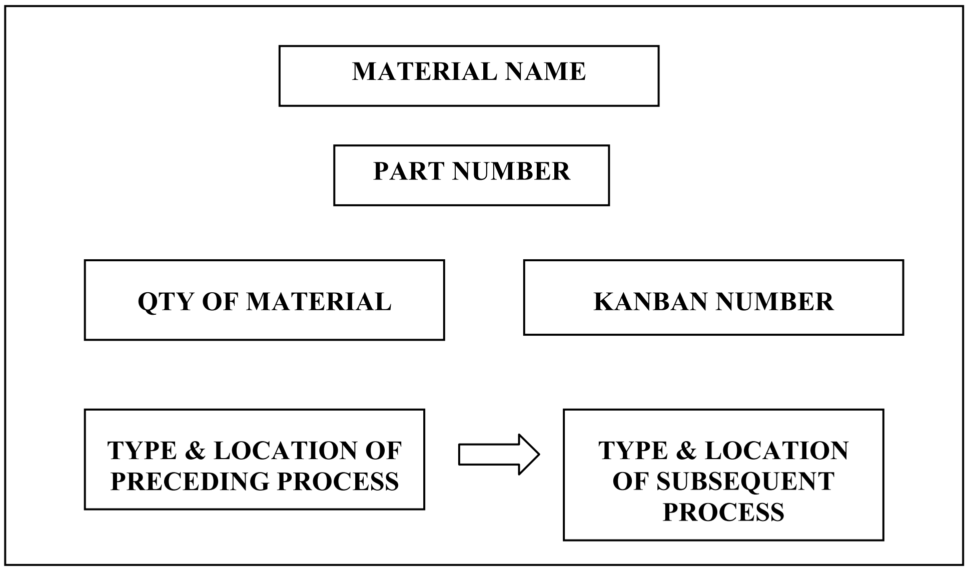


Figure 2.3 Schematic representation of a general kanban

The Kanban system was first implemented in Toyota automobile production system as part of the JIT production management concept. It aims to fulfill the objectives of increasing profit through production cost reduction, minimizing or eliminating waste in manufacturing, and inventory control with quality assurance. The success of the Kanban system in reducing work-in-process inventory and overproduction, without compromising quality of products, has brought about its interest in other manufacturing

* *Note: "kanban" when written with a lower case "k" denotes the meaning of a "card". "Kanban" written with an upper case "K" assumes a larger meaning as a system, such as the "Kanban system"*

industry to adopt a similar approach. The benefits of a Kanban system mentioned by Gross and Mclnnis (2003) are:

- Reduce inventory holding
- Improves material flow
- Eliminates overproduction
- Ensures control at material handling level
- Develops visual scheduling and process management
- Increased response to market
- Minimizes obsolete inventory
- Improve management of the supply chain

The traditional kanbans are essentially visual signals in the form of cards and can therefore be classified according to the types and functions that they perform within the manufacturing system. Huang and Kusiak (1996) have mentioned that kanban fulfills the function of visibility, production control and inventory control. The Japan Management Association (1985) also describes the functions of kanban as a work order providing information, an accompaniment for the actual material and an indication that the company carries out its tasks openly.

The implementation of the Kanban system throughout the entire manufacturing system and supply chain has led to several classification of kanbans based on the roles and functions that they perform. Monden (1998) has given a comprehensive list of the kinds of Kanban that exist within the Toyota production system, such as the *withdrawal* and *production kanban, supplier kanban, signal kanban, express kanban, emergency kanban, through kanban* and *common kanban*. Huang and Kusiak (1996) have further grouped the different types of kanban together into primary kanban, supply kanban, procurement kanban, subcontract kanban and auxiliary kanban. Table 2.2 provides a list and summary of the different types of kanban that has been discussed by the above-mentioned.

Table 2.2 Summary of different types of kanban

Types of Kanban	Kanban Category	Brief Description
Withdrawal Kanban	Primary Kanban	Authorizes the subsequent process to retrieve material of specific type and quantity from the preceding stage as indicated on the card
Production Kanban	Primary Kanban	Commands the preceding process to start manufacturing the same type and quantity of material that has been retrieved by the subsequent process
Signal Kanban	Primary Kanban	Plays the role of a visual indicator to specify when material manufacturing or replenishment order process should be started
Supplier Kanban	Supply/Procurement/ Subcontract Kanban	Similar to a withdrawal Kanban except that that the retrieval of materials is from a factory or storage location near the actual manufacturing plant
Express Kanban	Auxiliary Kanban	Issued once and returned after the material, that is to be retrieved by the subsequent process, is in shortage due to unforeseen circumstances
Emergency Kanban	Auxiliary Kanban	Issued once and returned when defective are present parts present in the material that has been retrieved by the subsequent process that needs to be replaced
Through Kanban	Auxiliary Kanban	Used in situation where consecutive processes are located very close together such that they can be regarded as a single process and therefore primary Kanbans are not required between these process
Common Kanban	Auxiliary Kanban	Plays the role of withdrawal Kanban as well as production Kanban where two process are located close to each other

2.3.1 Kanban System Model

The traditional Kanban system model makes use of the primary kanbans which are namely, *withdrawal kanban* and *production kanban*. Figure 2.4 describes how the *withdrawal* and *production kanbans* work between two consecutive manufacturing processes. The various steps involved in the flow of materials with the attached kanbans are listed below:

(1) Process Y collects material from material staging area (MSA) Y to manufacture its products. The MSA acts as a transition point for temporary storage of materials flowing between one process and the subsequent process. When the kanban box with the material is moved to process Y for manufacturing, the *withdrawal kanban* attached to the box is removed and placed on the Kanban container.

(2) When a *withdrawal kanban* is present in the kanban container, the material handler that checks the card container for the *withdrawal kanban* at regular intervals will attach the *withdrawal kanban* to an empty box and moves to product staging area (PSA) X.

(3) The material handler, holding the empty box and the *withdrawal kanban* as an authorization, will retrieve the product from the box in PSA X and place it in the empty box. The box that is now filled with the product and attached *withdrawal kanban* will be returned to MSA Y.

(4) The emptied box is now moved to process X while its attached *production kanban* is placed in the kanban container.

(5) When a *production kanban* is present in the kanban container, the operator in process X will start manufacturing the product. The finished product is then put in the Kanban box with the *production kanban* attached to it and returned to PSA X.

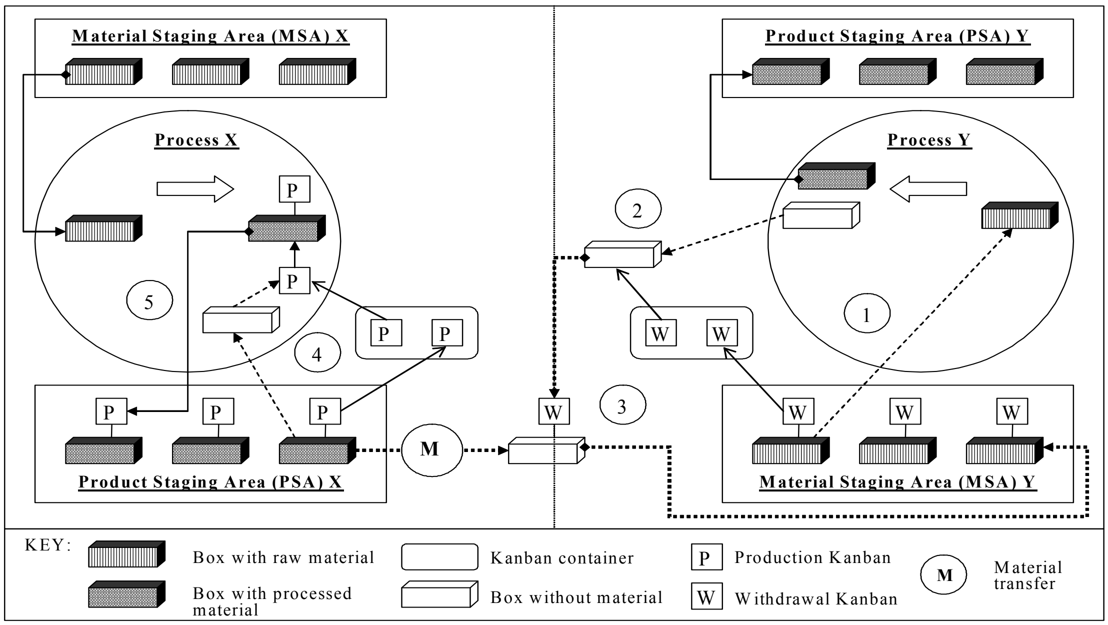


Figure 2.4 Traditional Kanban System Model

One observation made on the Kanban system model is that the flow of material is regulated by kanban boxes containing a specific quantity of materials, as indicated by the kanban which is attached to each box. Therefore it is necessary to know how the number of kanbans circulating between two consecutive processes is derived. The determination of an optimal number of kanbans that are allowed between processes is crucial so that the cost of holding additional inventory in the form of work-in-process (WIP) can be reduced or minimized. Generally the total number of kanbans between two consecutive processes can be calculated using the following formula (Huang and Kusiak 1996):

$$\text{Number of kanbans} = \frac{\text{average daily demand x lead time x safety factor}}{\text{Kanban box capacity}} \qquad (1)$$

where:

Average daily demand:	Refers to an aggregated value of product quantity that is to be manufactured per day to meet customer's demand. The information can be obtained from the production schedule of the manufacturing plant. Alternatively, the capacity and processing time of the process equipment may be used to determine this quantity.
Lead time :	This includes the manufacturing and waiting time of the preceding process as well as the amount of time needed to retrieve the material or deliver the material to the succeeding process.
Safety factor :	In strict JIT manufacturing environment, there should not be any safety factor as this will generally result in excess inventory or WIP. Flexibility is given to regulate this value depending on the dynamic stability of the material and process flow or confidence level of the management.
Kanban box capacity :	This refers to the maximum quantity of material that can be held during the transfer of material from one process to another. The quantity of material in the kanban box is indicated on the kanban accompanying it.

2.3.2 Key elements of Kanban System

A general description and illustration of the Kanban system model has been presented and some of these key elements that are crucial for the implementation of the Kanban system have been identified. These three key elements are summarized in Table 2.3. The JIT management concept and the various kanbans have also been discussed in the earlier sections. The determination of the optimal number of kanbans have generated much research interest in the topic judging from several research journal papers published over the past few years (Chang and Yih 2004, Hall, Bowden, Grant and Hadley 1998, Markham, Richard and Barry 2000). This research topic has led to a few variations arising from the traditional Kanban system which may ultimately benefit manufacturing companies searching for alternatives of the traditional Kanban system best suited for their manufacturing operations. These companies will have the flexibility to adopt the most appropriate system that fits their business model or operations.

Table 2.3 Summary of key elements in Traditional Kanban System

No	Key Elements	Description
1	JIT management concept	This is vital for the Kanban system to be implemented in the workplace. The use of the "pull" system in JIT will allow the company to achieve objectives of the Kanban system such as reduction in production cost, elimination of wastes and better inventory and quality control.
2	The kanbans	A visual signal that provides information to regulate the flow of inventory and materials. It contains such information as material part number, name, type, location of the preceding and subsequent process and quantity of material in the kanban box. The two commonly used kanbans are the withdrawal kanban and the production kanban.
3	Determining the number of Kanbans	The optimal number of kanban must be determined to ensure that inventory and WIP is kept to a minimum while allowing the Kanban system to be carried out smoothly without stock out.

2.4 Variations of the Traditional Kanban System

The traditional Toyota Kanban system has been proven to produce significant results in the reduction of inventory and elimination of waste in repetitive manufacturing systems. However, the effectiveness and application of the traditional Kanban system in a variety of other manufacturing environments remain as a challenge. This is due to factors that act as barriers to JIT implementation, such as non-repetitive manufacturing, systems controlled by job shop orders, dynamic fluctuation of production schedule or processing time, and difficulties in restructuring current material flow system from a complete 'push' system to a 'pull' system. Several authors have either discussed or proposed different variations of the traditional Kanban system to help these companies cope with uncertainties and difficulties arising from these factors. The following sections provide a brief discussion of these proposed Kanban systems that have evolved from the traditional Kanban system.

2.4.1 Single-Card Kanban

The single-card Kanban system, consisting of only the *withdrawal kanban,* was presented by Schonberger (1983). He believed that many companies used the single-card kanban initially before adopting the traditional Toyota dual-card Kanban system, if it is deemed necessary and beneficial in the later stages. The single-card system is actually not a true 'pull' system as materials are manufactured according to a "push" system using a daily production schedule, whereas delivery to the next work center is controlled by a "pull" system using a *withdrawal kanban*. Figure 2.5 provides a simple illustration of the single-card Kanban system.

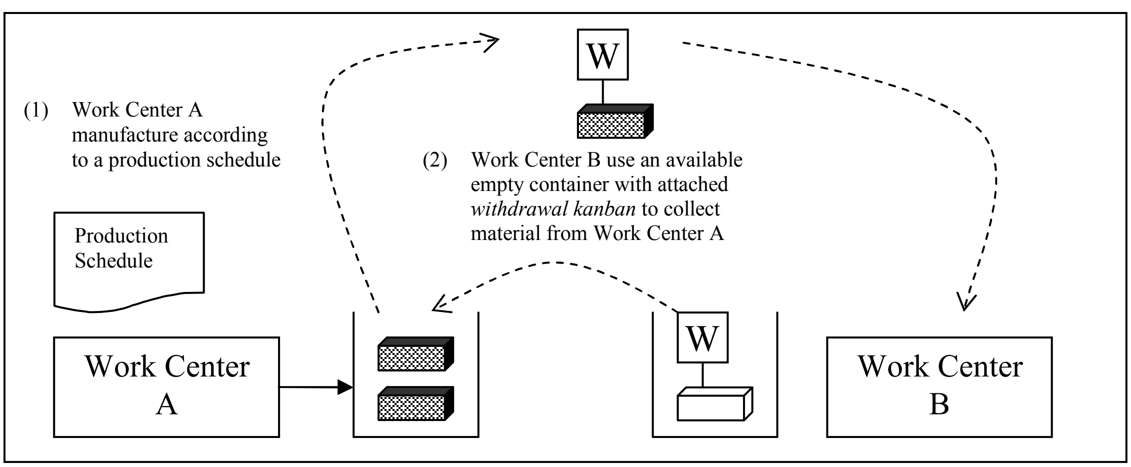


Figure 2.5 Withdrawal Single-Card Kanban System

The withdrawal single-card Kanban system is known to regulate the delivery of material parts from preceding work centers very precisely to ensure that the subsequent work centers do not have excess materials other than those that are in the process of manufacturing. There is also no material staging at the subsequent stage, but materials may be allowed to build up at the preceding stage.

Huang and Kusiak (1996) described another type of single-card Kanban system that uses *production kanban* instead of the *withdrawal kanban* mentioned in the earlier case. This system operates entirely as a 'pull' system and uses the *production kanban* to authorize work centers to start production. Figure 2.6 is an illustration of this type of single-card Kanban system.

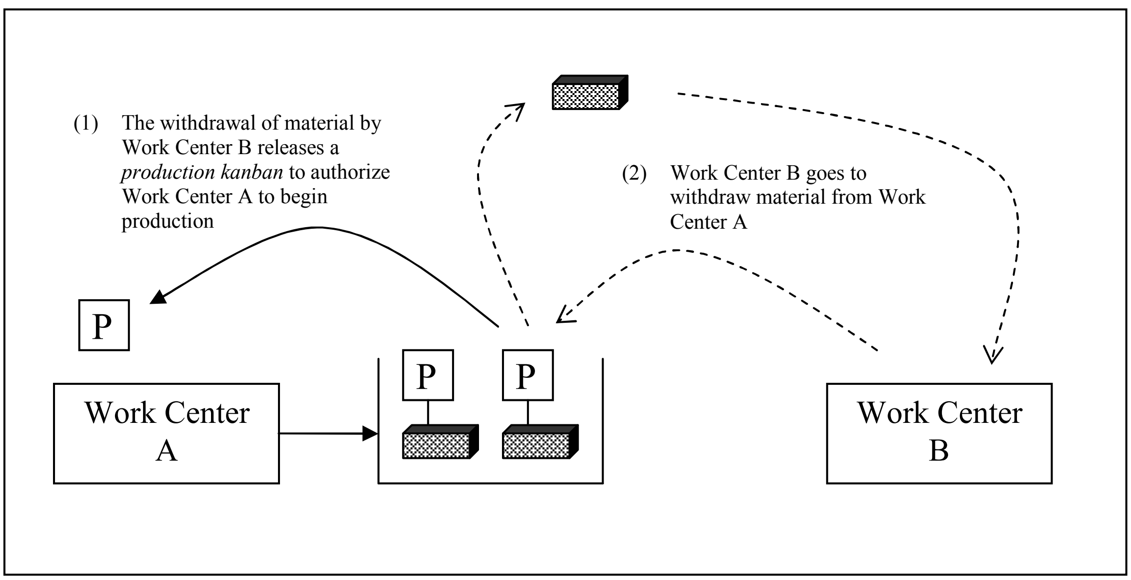


Figure 2.6 Production Single-Card Kanban System

The production single-card Kanban system is suitably employed in areas where there is low WIP and the turnover of kanbans can be achieved in a relatively short time. The absence of an additional buffer at the subsequent stage also provides space savings in work centers with limited space for buffer.

2.4.2 CONWIP (Constant Work In Process)

The CONWIP system is a generalized system which shares the benefits of a Kanban system. It is proposed by Spearman, Woodruff and Hopp (1990) and is believed to be more applicable to a wider range of manufacturing environments, especially those that rely heavily on material requirements planning (MRP) system. The *production kanbans*, which are attached to standard part containers, flow through the entire production line instead of individual work centers. The kanbans will only be detached from the containers and returned to the beginning of the line when it reaches the end of the production process. In this way, the entire WIP of the production line are kept constant throughout and thus its name CONWIP (constant work in process). Figure 2.7 shows a simple illustration of the CONWIP system.

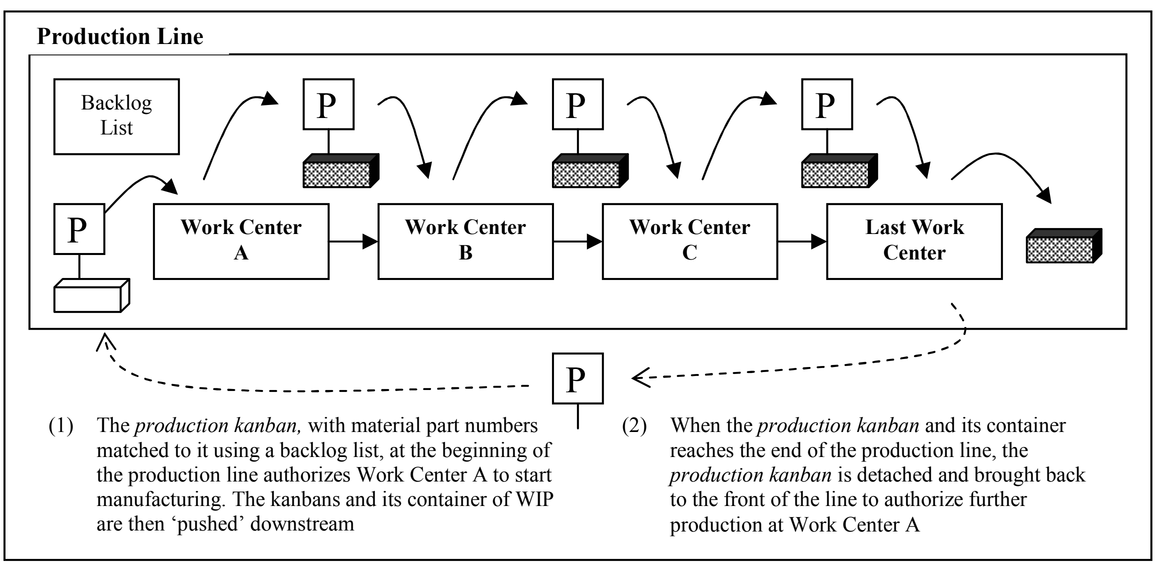


Figure 2.7 CONWIP system

From Figure 2.7, it is noted that the material part number sequences are controlled by the backlog list at the beginning of the production line. The 'pull' system exists only between the last and first work centre while the materials are 'pushed' downstream after the first centre to the last work centre. In a production line with a distinct bottleneck, the CONWIP system will allow WIP to accumulate at the bottleneck to allow for maximum utilization as compared to the traditional Kanban system.

2.4.3 Generic Kanban System

The generic Kanban system is designed specifically for dynamic manufacturing environments where processing time and demands vary constantly. Chang and Yih (1994) proposed the generic Kanban system by modifying the original Kanban system's operation discipline. Figure 2.8 shows a simple kanban and material flow of the generic Kanban system.

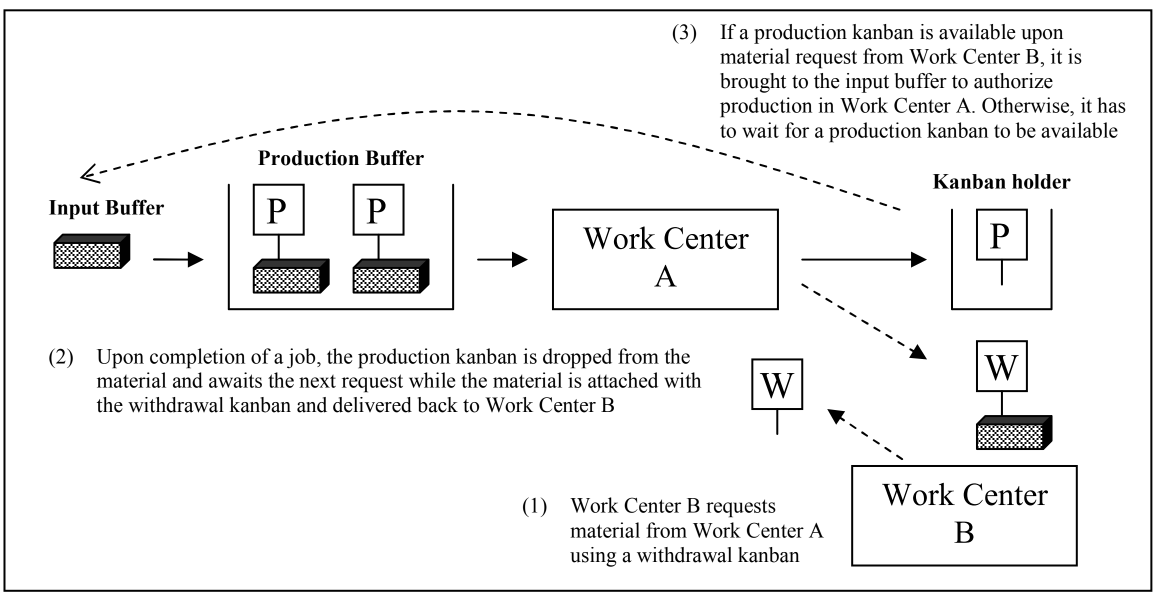


Figure 2.8 Generic Kanban System

The generic kanban operates in a dynamic environment where the master production is assumed not to be available. Production at the last work center of a production line will only begin when there is a demand. It is observed that in the generic Kanban system, only the kanban cards are available initially at the output of the work station instead of the finished jobs. This translates to waiting time incurred whenever the subsequent work center requests for materials as it needs to wait for the work center to finish the jobs. It can also be noted that the number of production kanbans assigned to each work centers will determine the WIP level and production lead time of the system. In the simulation study carried out by Chang and Yih to compare the traditional Kanban system and the CONWIP system, the generic Kanban system exhibited simpler production control and better performance over the former two. However, it was also noted that the generic Kanban system does not possess all the benefits of the traditional Kanban system.

2.4.4 Flexible Kanban System

As the implementation of the traditional Kanban system in JIT manufacturing faces several uncertainties such as varying demands or process lead time and interruptions resulting from preventive maintenance or equipment failure, Gupta, Al-Turki and Perry (1999) came up with the flexible Kanban system to address these issues. The flexible Kanban system operates similarly to the traditional Kanban system, except that it permits the fluctuation in the number of kanbans within the production line. In this way, the system is allowed to cope with uncertainties and interruptions that occur during the manufacturing cycle. Figure 2.9 demonstrates the operating model of the flexible Kanban system under four different manufacturing conditions.

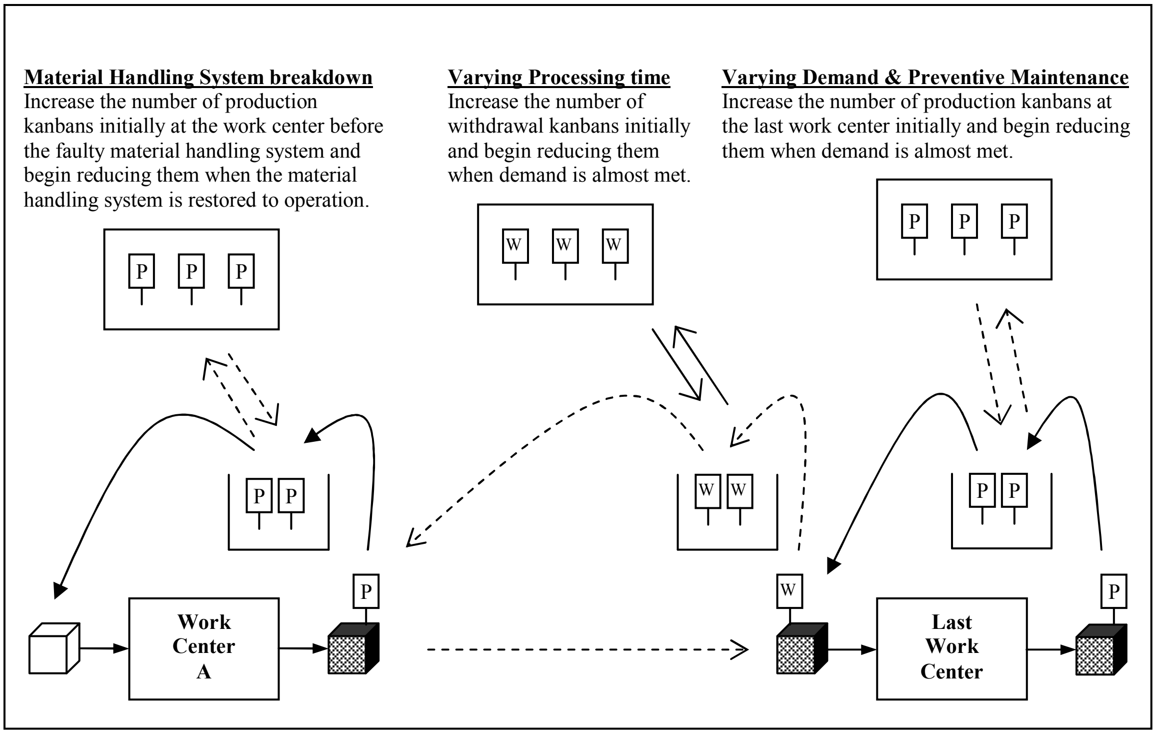


Figure 2.9 Flexible Kanban System

The main concept behind the flexible Kanban system is to increase the kanbans when a need to improve the production system performance arises and remove the extra kanbans when their presence brings about reduced system performance subsequently. This ensures that the work centres will not be blocked or starved due to the limited number of kanbans present in the traditional Kanban system and prevents the retardation of the entire flow of production that could have resulted in reduced throughput and completion time. Nevertheless, the authors mentioned that challenges, such as determining the time at which the extra kanbans should be added or withdrawn and specifying the number of extra kanbans, needs to be addressed before the flexible Kanban system can be implemented which would otherwise remains as a conceptual philosophy.

2.5 Challenges/Problems of the Traditional Kanban System

Although the traditional Kanban system, which makes use of the physical cards (kanbans) to regulate the material flow and has proven to be effective, there remains certain limitations within the system. Some of the problems and challenges associated with most of the Kanban systems mentioned in the earlier sections can be easily identified. Ansari and Modarress (1995) have also highlighted some of these problems. Table 2.4 presents the problems associated with the traditional Kanban system.

Table 2.4 Problems associated with the traditional Kanban system

Problem	Reasons
Lost of kanbans	The kanbans had to be handled regularly by removing from the box and reattaching or placing it in the material box or Kanban container. This increases the chance of the cards being accidentally misplaced which could result in material shortage for the subsequent process.
Too many kanbans	As the demand for certain products or the capacity for the resource in the subsequent process could be large, several kanbans may be required for the Kanban system to operate. In addition, subsequent work center in an assembly line may require many materials from several preceding work centers. Eventually, tracking of these kanbans may be loss and the flexibility of regulating the number of kanbans due will be made more tedious and time consuming.
Handling time of kanbans	The additional time incurred in removing and attaching the kanbans can be translated into longer lead time for determining the number of kanbans between work centers. This will eventually results in higher inventory or WIP throughout the entire manufacturing supply chain which the Kanban system initially seeks to reduce.
Increased withdrawal time	As the distance between processes is long, increased retrieval time must be used to compute the number of kanbans since the preceding process will only start production upon receiving the production kanban.
Regulating the number of kanbans	It is time-consuming to determine the number of kanbans for all the materials in every process. This is considered non value added activity in JIT philosophy and should be minimize or eliminated

The problems associated with the traditional Kanban system listed in Table 2.4 and the requirements for continuous improvement in manufacturing systems have led many companies to explore new solutions to improve their Kanban system. The recent rapid advances in Internet technologies have brought about many innovative developments in Web-based application software. Toyota has also mentioned about the benefits of their new 'e-kanban' system using the Internet in 2000 to speed up communications with its suppliers (Cullen and James 2002). Manufacturer Hunt Corporation has also reported improvement in inventory performance and delivery with their 'e-kanban' system (Inventory Management Report 2003). Nevertheless, they do not provide a clear description of the Web-based Kanban model due to the fact that their 'e-kanban' system is company and domain specific, which is only customized for their own business model. The evident adoption of Web-based technology by these two multi-national companies into their manufacturing system has helped to pave the way for an opportunity and vision to develop a generic Web-based Kanban system to overcome the problems and challenges mentioned.

Chapter 3: Web-based Kanban Development

3.1 A Proposed Web-based Kanban System Implementation

A general Web-based Kanban system has been proposed based on the key elements of the traditional Kanban system model discussed in the earlier section. Figure 3.1 presents an implementation model of the proposed Web-based Kanban system between two process work centers. The various steps involved in the flow of materials using the Web-based system are given below:

[1] Process Y collects material from Material Staging Area (MSA) Y to manufacture its product. As the Kanban box with the material is moved to process Y for manufacturing, the material handler will activate the *withdrawal Kanban* signal and place it in 'on-hold' status on Web-based Kanban screen 1.

[2] The *withdrawal Kanban* signal from Kanban screen 1 will be translated to a *production Kanban* signal on Kanban screen 2 located at Process X. The operator will acknowledge the production signal and changed it to 'in-process' status. Process X will then begin manufacturing process immediately when this *production Kanban* signal is received.

[3] The *withdrawal Kanban* signal that is in 'on-hold' status on Kanban screen 1 will also authorize the material handler to retrieve the material from the material box in Product Staging Area (PSA) X using the empty box from Process Y. Signal will be set to 'in-process' as he goes to replenish the material from Process X.

[4] After the collection of material from PSA X, the material handler will return the replenished material to MSA Y. At the same time, the material handler will deactivate the *withdrawal Kanban* signal on Kanban screen 1 and set it to 'normal'.

[5] After Process X has finished manufacturing the product, the Kanban box with the finished product will be returned to PSA X. Similarly, the production signal on Kanban screen 2 will be deactivated at the same time and set to 'normal'.

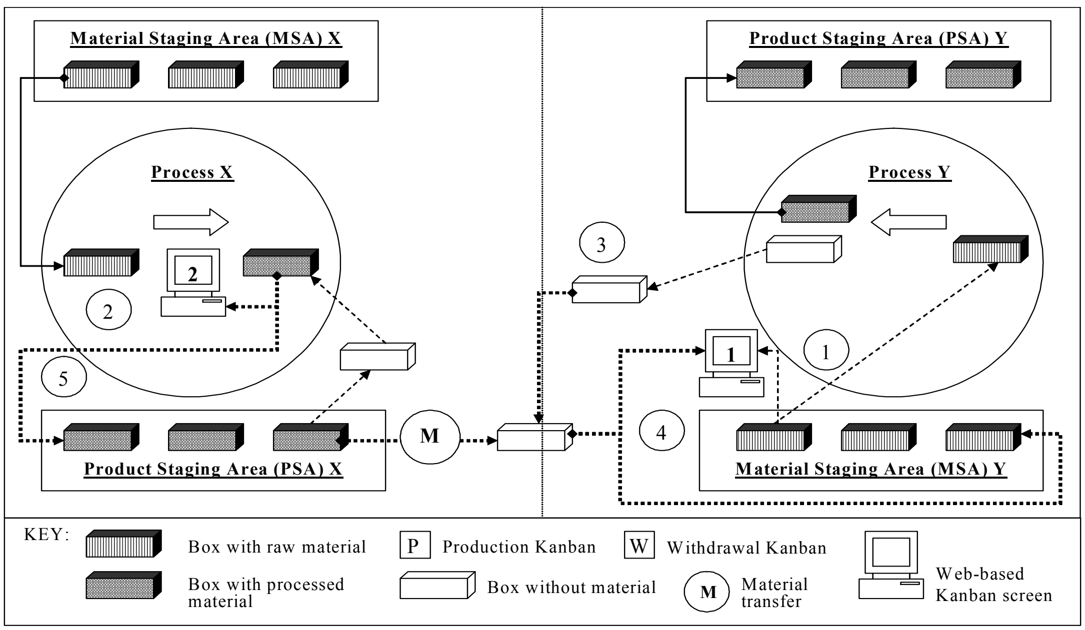


Figure 3.1 Implementation Model of the Proposed Web-based Kanban System

The implementation model of the proposed Web-based Kanban system is similar to the traditional Kanban system except that physical kanbans are now replaced by kanban signals propagated using Web-based technology. Recently, the advent and widespread use of wireless networking technology has made the setup of a Web-based system much simpler and easier compared to companies that previously employed wired local area network (LAN). Such wireless web-based technology will soon be a cutting edge platform within manufacturing companies that plans to compete in terms of faster information flow and product time to market.

3.2 Architecture Framework of the Web-based Kanban System

The general architecture framework of the Web-based Kanban is proposed in Figure 3.2. The material handlers and a system moderator are the key end-users of the Web-based Kanban system. The basic infrastructure of the framework includes the client's Web browser and the Web/application server that supports information flow between communicating processes/parties in the manufacturing environment. The open Internet standards TCP/IP and HTTP provide interoperability protocols to establish communication between the Web client and the Web/application server. The main functional modules and the information database are hosted on the Web/application server which may be implemented for the Internet or company Intranet. The Internet will allow suppliers and customers to collaborate and interact more readily in the supply chain, while the Intranet offers better security and responsiveness.

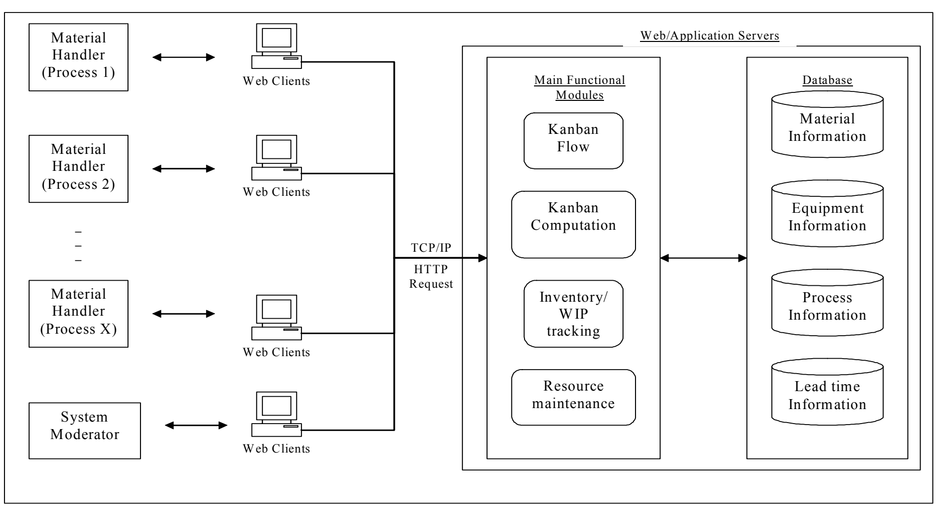


Figure 3.2 General Architecture Framework of Web-based Kanban

In order for the Web-based Kanban system platform to operate effectively, four different functional modules have been identified: *inventory tracking module, resource maintenance module, Kanban flow and computation module*. Figure 3.3 depicts the process flow relationship of the four functional modules within the Web-based Kanban system environment.

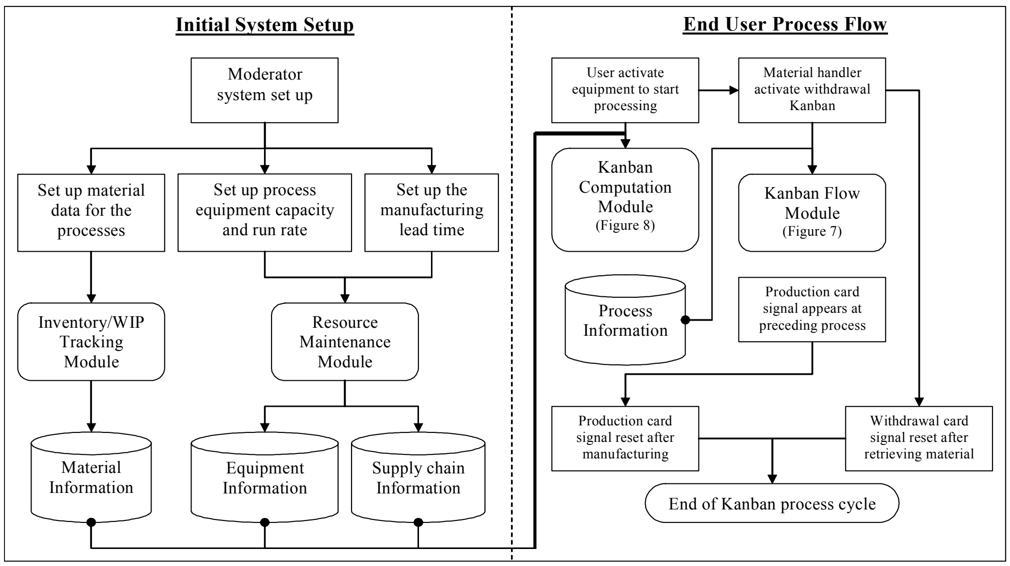


Figure 3.3 Functional Modules of Web-based Kanban

The *Inventory Tracking Module* functions as the back bone of the Web-based Kanban system architecture. It maintains a record of the materials and inventory/WIP level within the assembly plant. The moderator will update the system with materials requirements for the product assembly. Alternatively, the Web-based Kanban system can also be integrated with the bill of materials (BOM) system so that the material database can be updated automatically whenever new products are being introduced. The *Inventory Tracking Module* will also keep track of assigned or unassigned materials within the assembly plants to facilitate auditing and stock maintenance. Materials that are delivered to the assembly plant will have pertinent information such as part number and delivered quantity captured into the system using a bar code system or a part number capturing system. This information will be supplied to the *Kanban Computation Module* when in the later stages upon request.

The *Resource Maintenance Module* identifies the status of the assembly and processing equipment/machinery. The capacity, processing time and travel time between processes are critical information during Kanban computation. The accuracy of this information is critical in order to ensure that the Web-based Kanban system operate effectively. A viable method to ensure the credibility of the information is to extract the required data directly from the manufacturing resource planning (MRPII) database system of the assembly plant. Alternatively, the moderator can obtain information related to the status of the processing equipment/machinery from the equipment or industrial engineer prior to the input of these information into the system. These data will be transferred to the *Kanban Computation Module* to determine the number of kanbans when manufacturing assembly begins.

The *Kanban Computation Module* helps to determine the number of kanbans between processes. When a particular assembly process is scheduled to start production, the supervisor can choose to activate the particular process to be linked to the Web-based Kanban. The system will then automatically gather information relating to the types of materials required by the process and the status of the processing equipment, such as lead time and capacity, which has earlier been supplied by the inventory tacking module and resource maintenance module earlier. Using the standard kanban computation methodology given in equation (1) of Section 2.3.1, the system will perform a computation and inform the material handler of the number of kanbans available for use and the material quantity per kanban container/box delivered to the process. If there are several processes using the same type of materials, the *Kanban Computation module* will also perform aggregation or risk pooling for the kanban request quantity. This function is crucial, especially for kanban pull between the assembly plant and suppliers, as small order quantities are often undesirable due to reasons such as additional tasks involved in breaking bulk orders and consideration of bulk discount for larger quantity. If relevant information is supplied to the Kanban computation module, it can also provide decision support to the user, giving details such as the availability of the materials currently in the preceding process or assembly plant, so that the user can prepare equipment setup for the next assembly operations, or determine if the current process can be carried out immediately if the materials are available.

The *Kanban Flow Module* is the basic building block of the Web-based Kanban system. It provides the user interface for the equivalent flow of kanbans between processes and tracks the movement of the kanbans across the manufacturing supply chain. As the Kanban functions mainly as a visual signal, this module will also play a crucial role of displaying the details of the circulating kanbans. Information pertaining to materials required by the assembly process, such as material name and its associated part number found in the traditional Kanban, will be made available on the screen for the user. Another main function of this module is to allow the user to issue kanbans to the preceding process and to acknowledge the receipt of kanbans by the subsequent process.

The user will issue kanbans by sending a signal via the Web-based Kanban when material is demanded for the current process. The preceding process will also acknowledge the request signal through the system and can choose to either deliver the requested material to the current process or prepare it for collection by the material handler.

3.3 Roles & Workflow Management

The Web-based Kanban system platform can be classified into three different roles and workflow environment: moderators, supervisors and material handlers. Figure 3.4 presents a simple workflow management summary of the Web-based Kanban system.

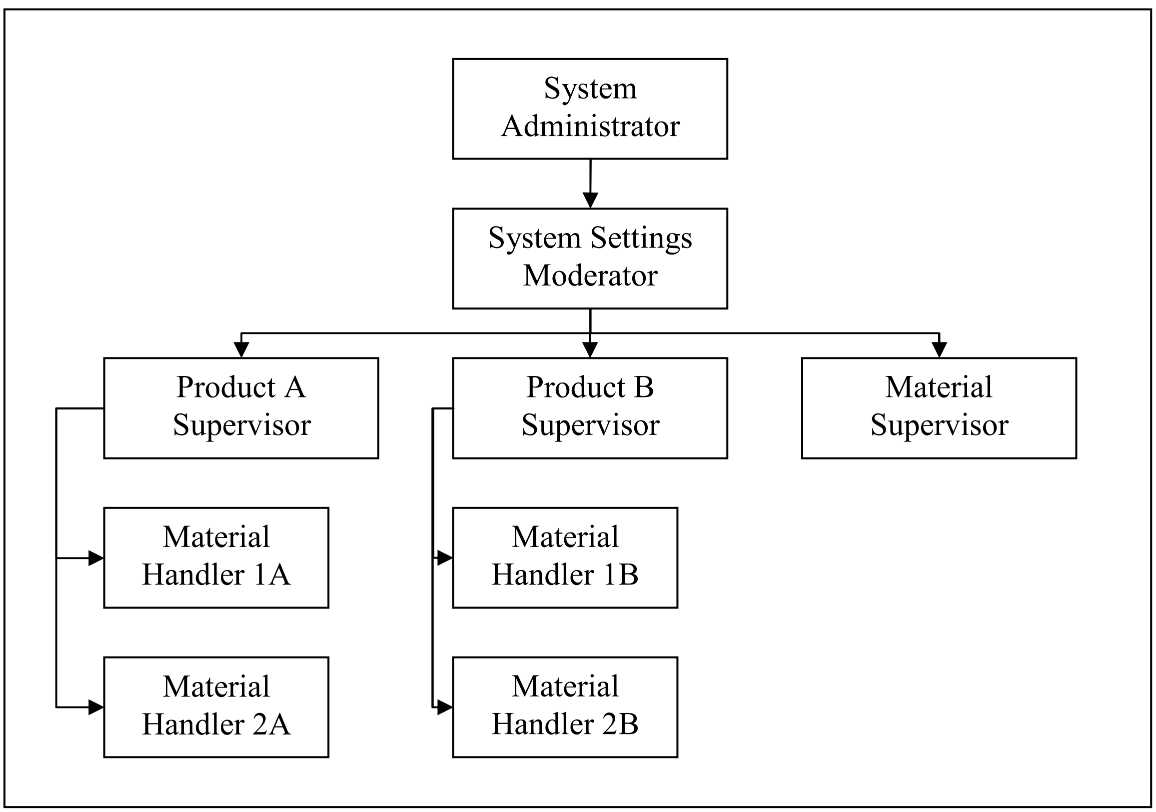


Figure 3.4 Workflow management within Web-based Kanban Environment

The moderators consist of the system administrator and system settings moderator. The system administrator maintains the operation of the entire Web-based Kanban system application. The system settings moderator takes charge of critical information related to the kanban pull operations such as delivery lead times from suppliers to the plant and between different processes within the plant. The system moderator must also ensure that process equipment database is updated regularly so that the system can accurately determine the number of Kanbans during Kanban computation.

The supervisors consist of the product supervisors and the material supervisors. The product supervisors lead the material handlers and ensure that standard operational procedures are carried out accordingly. They are also tasked to manage the product assembly lines and will manufacture according to the production or demand schedule. Based on the schedule, the product supervisors will choose to activate assembly lines accordingly using the Web-based Kanban. For every assembly operations or process activated, the system will automatically compute and generate the required Kanbans to start the assembly operations. The product supervisors must then carry out assembly shop floor supervision to ensure that the material handlers adhere to Kanban pull methodology.

The material supervisors are responsible for ensuring material part numbers kept in the system database are updated so that materials designated to specific products according to the bill of materials can be retrieved accurately by the system during the Kanban computation process. The inventory holding level of all the materials is also monitored and any discrepancies between the database system and the actual holding stock have to be updated immediately.

The material handlers are the main users of the system. They are assigned to specific process across the entire assembly lines and are required to request for materials according to the methodology of a Kanban 'pull' system as described in the earlier sections. *Withdrawal kanban* and *production kanban* signals are activated by the material handlers and they may also take on physical tasks on the assembly process if it is a non-automated assembly line.

3.4 Web-based Technology Platform

The World Wide Web (WWW) started as a static and unidirectional medium for information flow a decade ago by publishing contents in simple Hypertext Markup Language (HTML) files. Today, the WWW has been transformed into an arena of dynamic and interactive medium that serves as a viable channel for commercial transactions and communications activities. The rapid advancement of WWW has been attributed to the successful development of several dynamic Web-based platform models such as the Common Gateway Interface (CGI), PHP Hypertext Processor (PHP), Active Server Pages (ASP) and Java Server Pages (JSP). The selection of these dynamic platforms to be deployed by the proposed Web-based Kanban system depends on several factors such ease of programming, reliability, portability and its associated performance with the system. The following section provides a brief assessment of the above mentioned platform models.

3.4.1 Common Gateway Interface (CGI)

The CGI was one of the earliest Web-based technology standard used for interfacing between external applications and information Web servers (Anthony 2000). Coding in CGI scripts allows data to be sent dynamically using HTTP to the client Web browser and facilitating real time interaction between the user and the server. When a client sends a URL request that connects to the CGI script, it executes and creates a new process for the command written within the script. Real-time information is exchanged through user inputs such as variables in forms and the CGI process outputs that are transmitted to the client Web browser. The CGI process will terminate once the information exchange is completed. The CGI can be written in various different types of programming language such as PERL or C++. Figure 3.5 shows a simple working architecture of CGI.

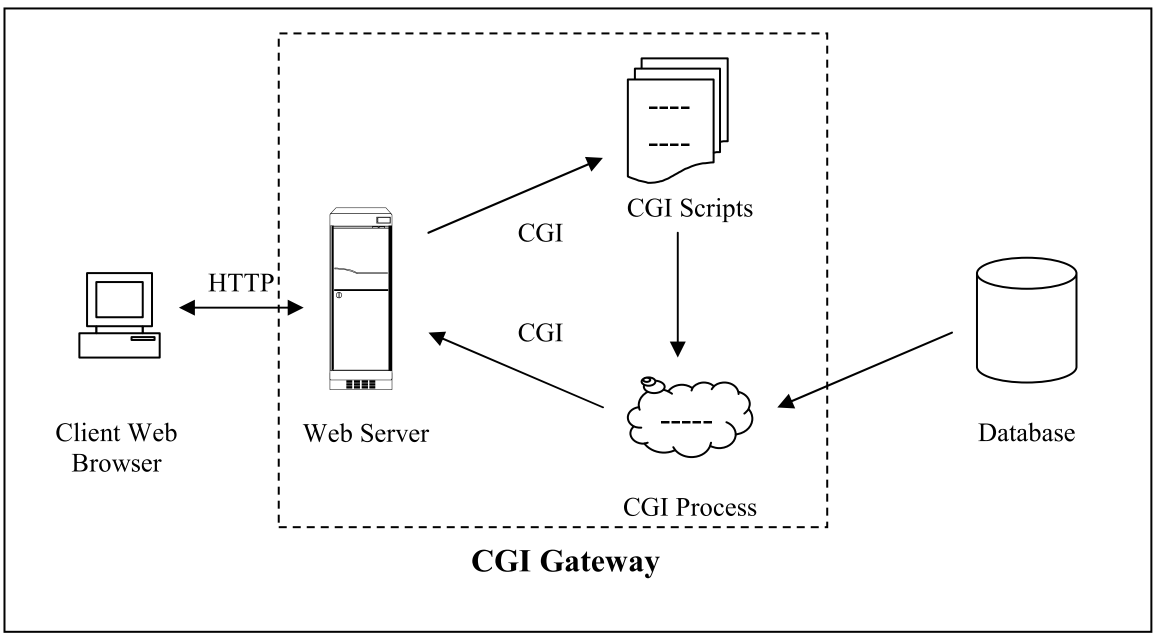


Figure 3.5 Simple Architecture of CGI

Although CGI can provide real time information exchange, CGI scripts are often inefficient to be used for writing Server extensions (Lan, Ding, Hong, Huang & Lu

2003). Its performance is mostly affected by the number of processes consuming huge amount of system resources which are created each time a dynamic request is made with the server (Varsha, Tony & Paul 2003). There are also several security concerns such as unauthorized access by clients due to CGI programming errors raised by Anthony (2000) when implementing CGI in corporate environment.

3.4.2 PHP Hypertext Processor (PHP)

PHP is categorized as an open source server-side programming language used to construct dynamic Web pages (Zend Technologies 2001). Unlike CGI scripts, PHP scripts are embedded within HTML encoding using Web browser as the user interface. The PHP script process executes within the HTML codes and access required information database concurrently to produce dynamic contents in the client Web browser. PHP can be implemented using a three-tier architecture which helps to provide clearly defined structure for your application, scalability and ease of maintenance (Jason 2001). A simple three-tier PHP architecture is shown in Figure 3.6.

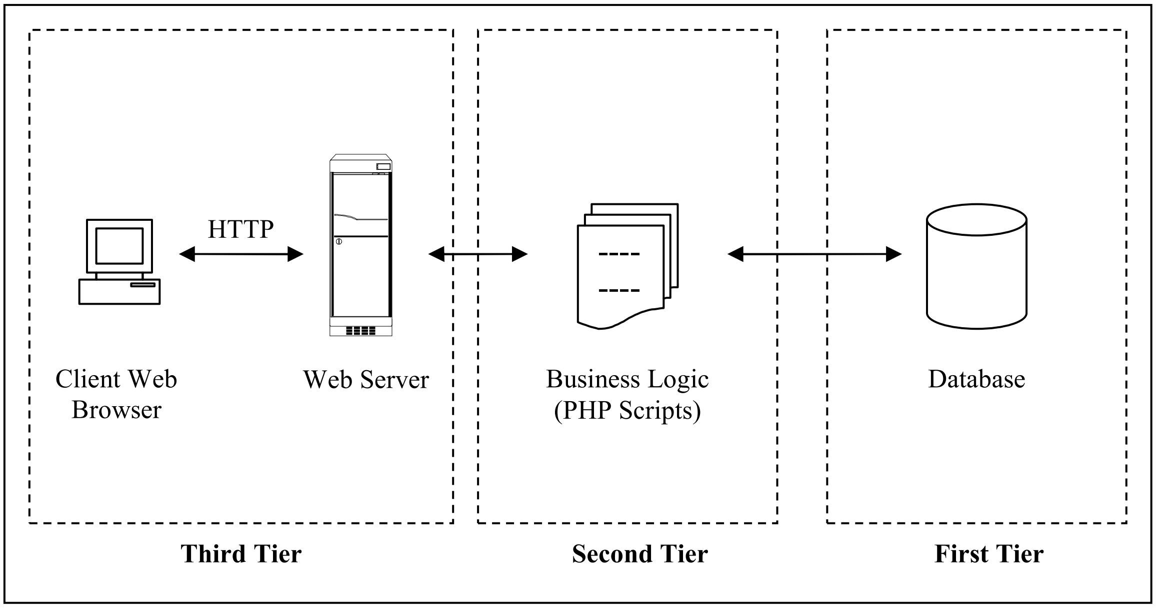


Figure 3.6 A Simple Three-Tier PHP Architecture

There are several strengths and weaknesses mentioned by Sean (2004) about deploying PHP as the server scripting language. The advantages of using PHP includes open source, ability to integrate with popular server Apache and effective memory usage and execution due to its smaller code path to minimize server side code execution. In addition, PHP is highly portable can be implemented across several platform such as Unix and Windows. Nevertheless, PHP still have some shortcomings that needs to be addressed such as lacking in error-based event-handling instances and weak object oriented programming (OOP) model. Weak abstraction for databases is also one of the primary concerns of deploying PHP in an Enterprise Information System (Lan, Ding, Hong, Huang & Lu 2003)

3.4.3 Active Server Pages (ASP)

ASP is another server-side scripting language created by Microsoft Corporation to generate interactive and dynamic Web pages (Gladwin & Copeland 2001). Microsoft introduced ASP primarily to overcome performance issues caused by CGI due to its huge resource consumption (Gibbs 2002). ASP can be written in either Visual Basic (VB) Script or Javascript (JS). Similar to PHP, ASP scripts are embedded within HTML Web encoding and executes in the server when a Web browser makes a request. Figure 3.7 presents a simple three-tier ASP architecture which is similar to PHP except that the Web-based server deployed has to be Microsoft's Internet Information Server (IIS) in order for ASP to run.

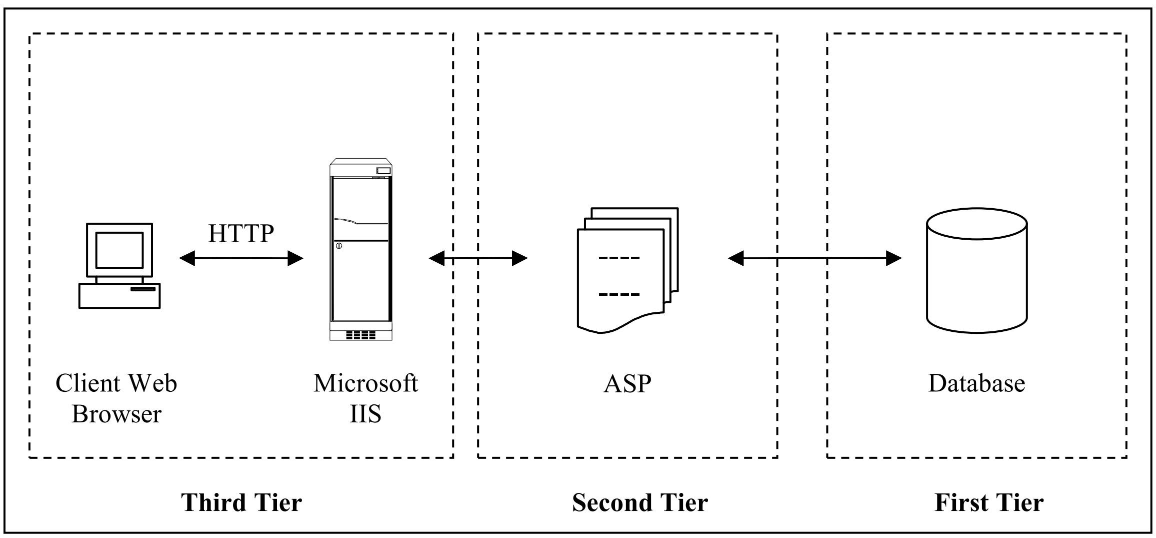


Figure 3.7 A simple Three-Tier ASP Architecture

Although ASP has proven to be efficient because of its ability to take advantage of multithreading architecture, its implementation platform is limited to only Microsoft IIS that can became unstable and crash easily if there are instances of simple scripting mistakes (Lan, Ding, Hong, Huang & Lu 2003). In a comparison made between PHP and ASP, Sean (2004) mentioned about the higher consumption of memory and execution time using ASP due to its longer code path inevitably translate to high loading on the server, causing it to become unstable easily.

3.4.4 Java Server Pages (JSP)

JSP is part of the Java 2 Enterprise Edition (J2EE) development platform introduced by Sun Microsystems Inc. specifically for the implementation and deployment of enterprise applications. The success of J2EE is attributed to the fact that the platform is designed through an open process that engages the participation of a range of industry enterprise vendors in computing (Singh, Stearns and Johnson 2002). J2EE is typically designed to support both client and server side development of distributed and multi-tier applications. It also offers programmers a number of application programming interfaces (API) for accessing the enterprise information system when deploying your applications in a business environment. There are several different types of application models available within the J2EE environment such as stand-alone client model, multi-tier applications model, Web-centric application model and business to business model. The three-tier web-centric model shown in Figure 3.8 is most widely deployed as a starting point for many J2EE applications due to its simplicity and ease of implementation (Singh, Stearns and Johnson 2002).

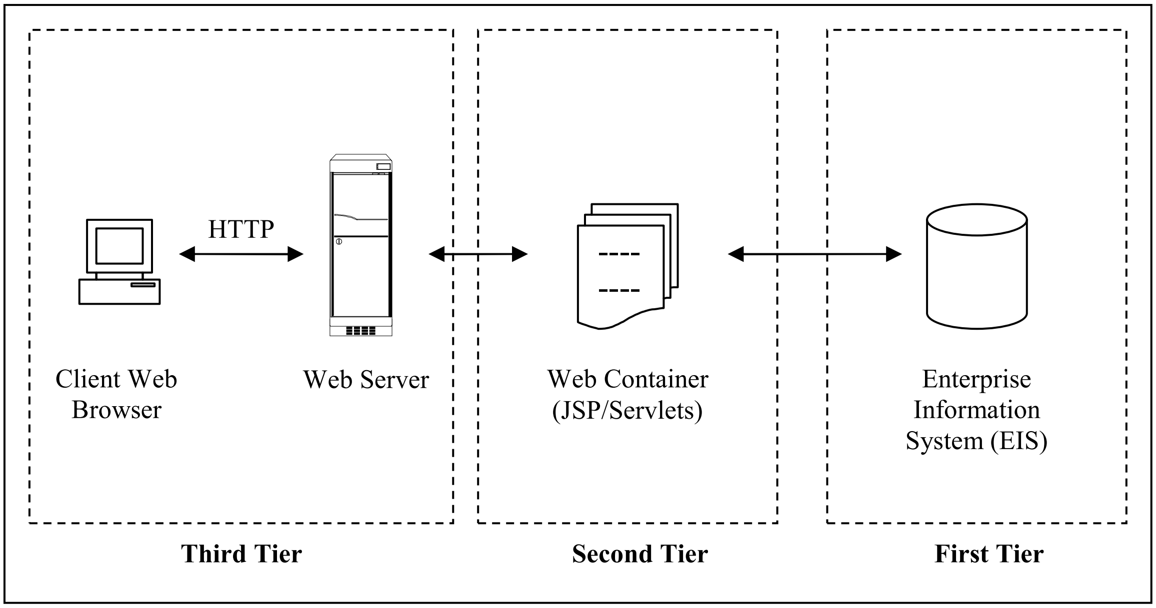


Figure 3.8 A simple J2EE Three-Tier Web-Centric Model

Comparing among the various types of server side scripting language programming available, JSP is more attractive in terms of platform independence, improved performance, ease of maintenance through separate handling of business logic from user display and the ease of use (Lan, Ding, Hong, Huang & Lu 2003). JSP also has the advantage over ASP as it can precompiled and cached on the Web server thus reducing the script execution time whenever a client call is made to the server. Nevertheless, JSP compels users to follow strict all-Java programming model such as making native calls only to Java classes or JavaBeans and requires Java Virtual Machine (JVM) as an interpreter for its complied byte code (Pankaj 1999). In a performance comparison of dynamic web platforms conducted by Varsha, Tony and Paul (2002), JSP's performance in terms of throughput at the client side also trails behind that of CGI scripts.

3.5 Technology Platform Requirement Specifications

During the selection of a suitable technology platform to be implemented as the Web-based Kanban prototype, several key requirements have been identified. A description of these requirements is listed in Table 3.1.

Table 3.1 Technology Platform Requirements

Requirements	Descriptions
Ease of Programming	The syntax and code structure of the programming language must be easily understood and allows programmers to understand the program logic and algorithms quickly.
Cross Platform	The ability of the developed prototype to be implemented and tested across various platforms.
Ease of Database Connection	The prototype must be able to make establish connection to various databases using available APIs easily.
Open source and widely supported	Open source allows programmers to share and resolve problems or issues quickly.
Low Cost in implementation	Low cost in terms of acquiring and setting up of the software prototype

Based on the technology platform requirements specified in Table 3.1, a platform requirements matrix shown in Figure 3.9 is constructed to assess the suitability of the Web-based technology discussed in the previous section. JSP emerged as the most suitable server side scripting language to be used as the Web-based Kanban prototype.

Web-based Technology	CGI	PHP	ASP	JSP
Requirements				
Ease of programming		√	√	√
Cross Platform	√	√		√
Ease of Database Connection	√		√	√
Open source and widely supported		√		√
Low cost in implementation				√

Figure 3.9 Platform Requirements Matrix

3.6 Prototype Implementation

A prototype of the Web-based Kanban system has been developed based on the proposed methodology using JSP as the underlying technology platform. The Web-based Kanban prototype architecture is shown in Figure 3.10.

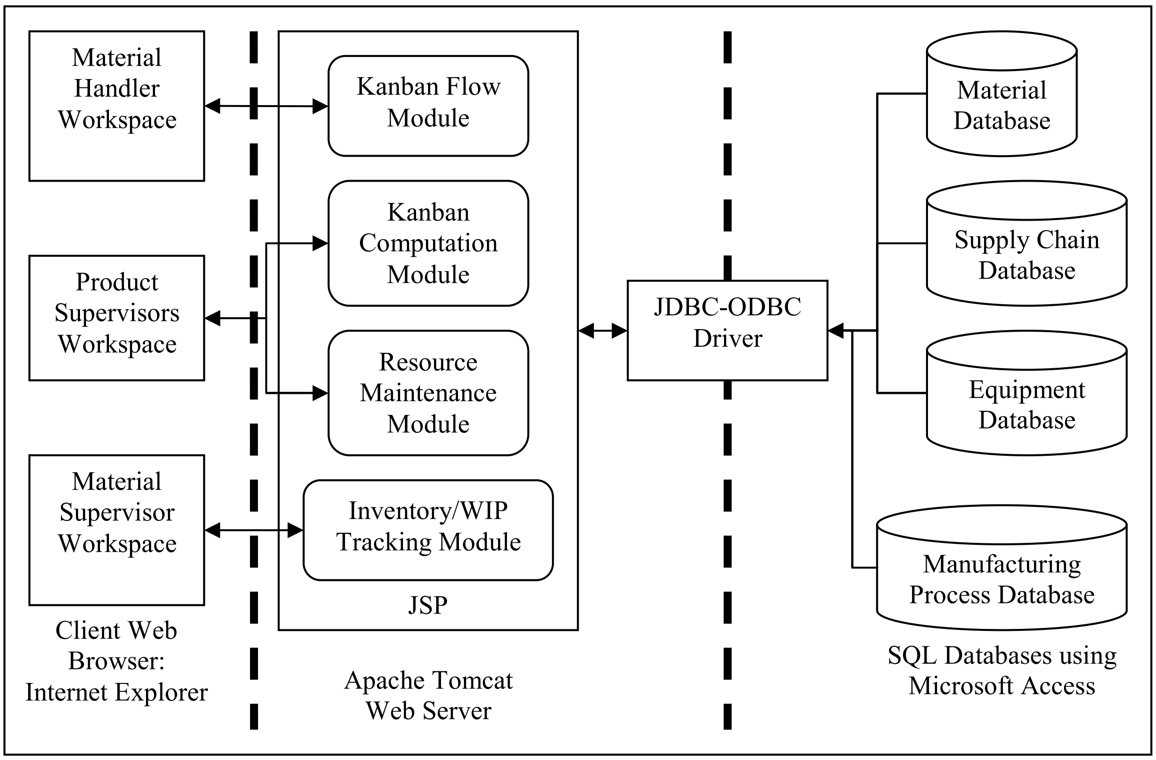


Figure 3.10 Web-based Kanban Prototype Architecture

The entire Web-based Kanban System is built using information communication network of the Internet and TCP/IP protocol. The client uses the Internet Explorer as the Web-browser to interface with the Web server Apache Tomcat. The Apache Tomcat is a servlet container distributed free by The Jakarta Project (http://jakarta.apache.org/tomcat/). Tomcat is also used as the official reference implementation for JSP technology. The four main modules of the Web-based Kanban system are hosted in Tomcat and employ the native JDBC-ODBC drivers to establish connection with the Microsoft Access SQL Databases.

Figure 3.11 shows the Web-based Kanban login screen, system's manufacturing supply chain lead time maintenance screen and average daily demand maintenance screen during setup. The moderator is allowed to configure the processes lead time and make changes to the daily demand per week using the edit function. These lead times are used to determine the number of kanbans in the later stage of the system.

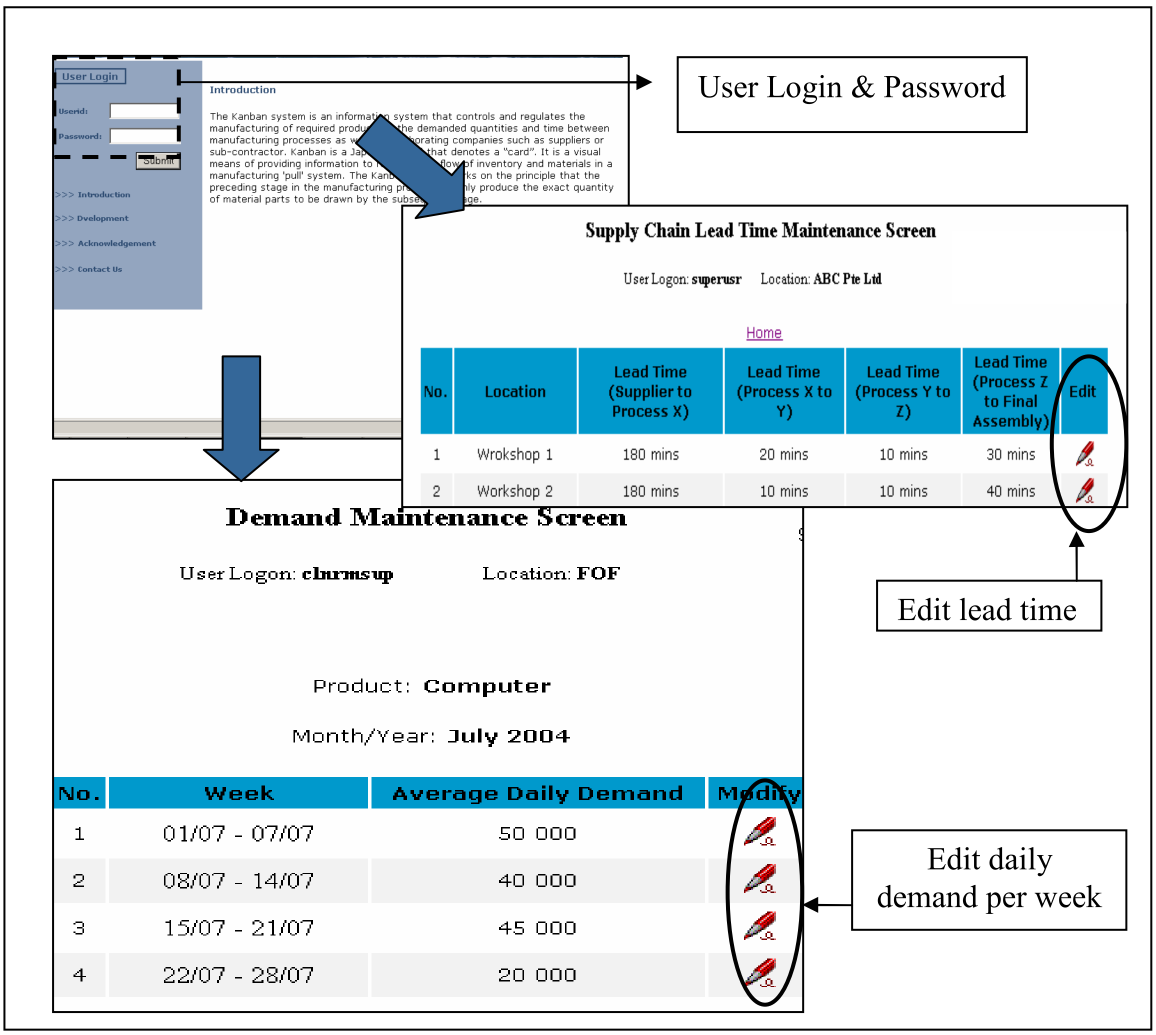
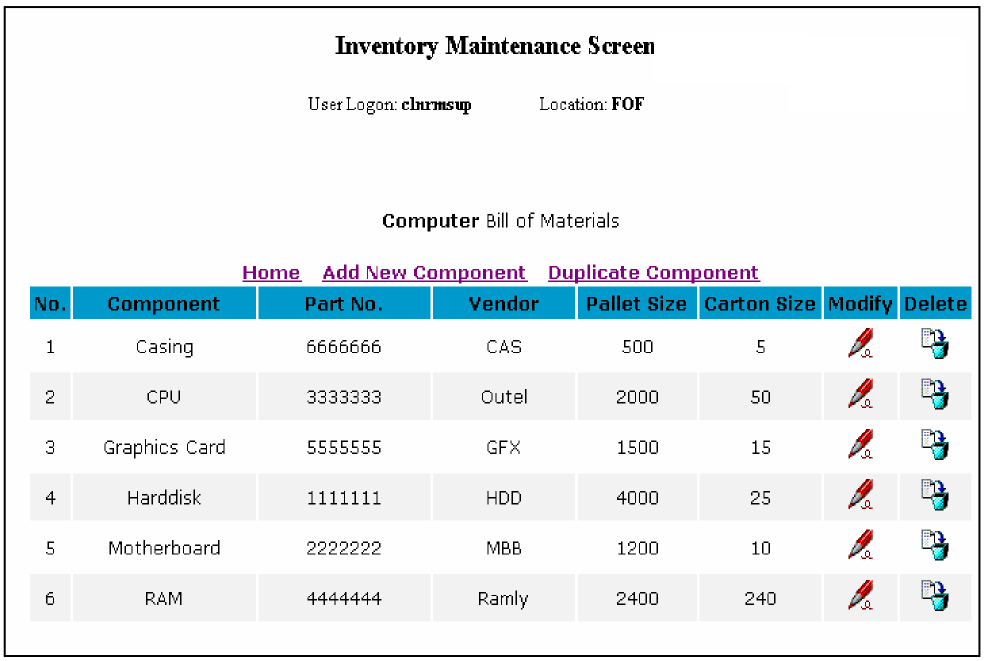


Figure 3.11 Web-based Kanban Login and Supply Chain Lead Time Maintenance

Figure 3.12 shows the product BOM and inventory maintenance screen. It allows the user to create new product and develop its associated BOM structure. If the products differ only in terms of configurations, the system will also allow the use to develop the new product using existing product BOM quickly by duplicating similar components. These materials can be then be extracted by the system to supply the Kanban system during the production or assembly processes.



Inventory Maintenance Screen

User Logon: **clurmsup** Location: **FOF**

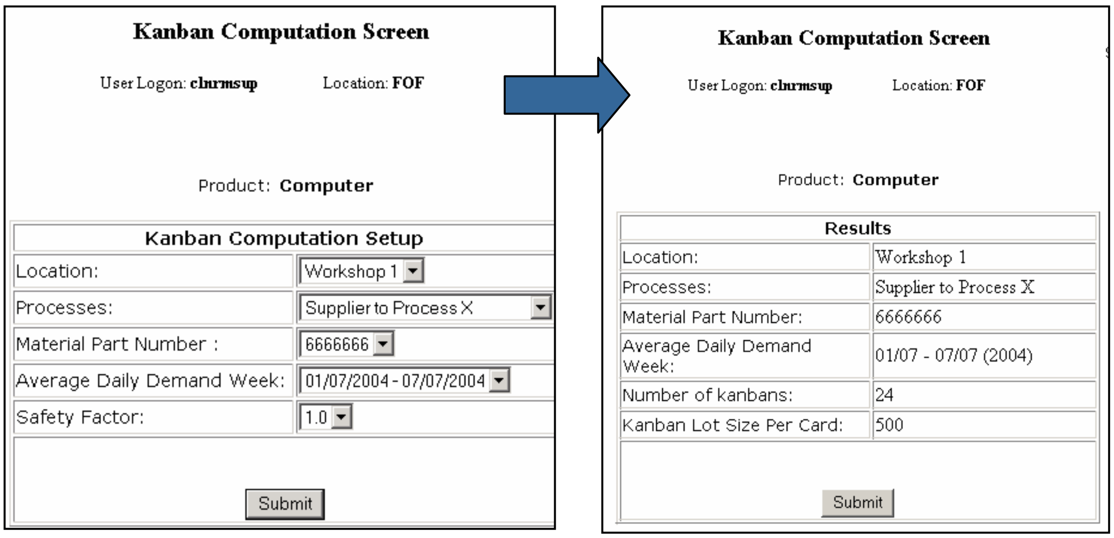
Computer Bill of Materials

Home Add New Component Duplicate Component

No.	Component	Part No.	Vendor	Pallet Size	Carton Size	Modify	Delete
1	Casing	6666666	CAS	500	5		
2	CPU	3333333	Outel	2000	50		
3	Graphics Card	5555555	GFX	1500	15		
4	Harddisk	1111111	HDD	4000	25		
5	Motherboard	2222222	MBB	1200	10		
6	RAM	4444444	Ramly	2400	240		

Figure 3.12 Inventory & BOM Maintenance Screen

Figure 3.13 depicts the how the Kanban computation module performs a calculation on the number of kanbans to be supplied between the Supplier and Process X. An example of the calculation is also given below the diagram. The user will need to specify information pertaining to Location, Processes, Material Part Number, Average Daily Demand Week and a Safety Factor. Based on the above mentioned inputs, the Kanban computation module will communicate via the JDBC-ODBC driver with the databases to extract the relevant data required in the computation. The computational result is returned to the user for verification and this can be submitted to be stored and retrieved by the Kanban flow module in the operational stages of the system.



Example

Assume:
Material = Casing (Part No: 6666666)
Kanban Container Size = Pallet Size = 500
Supplier to Process X lead tine = 0.2 days
Average daily demand for the week = 50 00(
Safety Factor = 1.2

Number of kanbans
= (Average Daily Demand x Lead Time x Safety Factor) / Kanban Container Size
= (50 000 x 0.2 x 1.2) / 500
= 24

Figure 3.13 Kanban Computation Screen

Figure 3.14 and 3.15 show instances of the user interface generated by the Kanban flow module. The number of kanbans in the Process Kanban screen is determined by the Kanban Computation module. The material handler activates the withdrawal kanbans by clicking on the blue “K” icon on the process Kanban screen to request material from the supplier. The system also displays the status of the Kanbans to determine whether kanban is available (denoted by the blue “K” icon), “in-process” or “in-delivery”. Subsequently, the withdrawal signal is received by the supplier maintenance screen when it refreshes the display at a constant time interval. The supplier will respond to the request once the material is delivered by clicking on the red "K" button that removes the withdrawal kanban signal in the supplier maintenance screen, but changes the "in-process" signal to "in-delivery" in the Process Kanban screen to indicate that material is on the way to the assembly line.

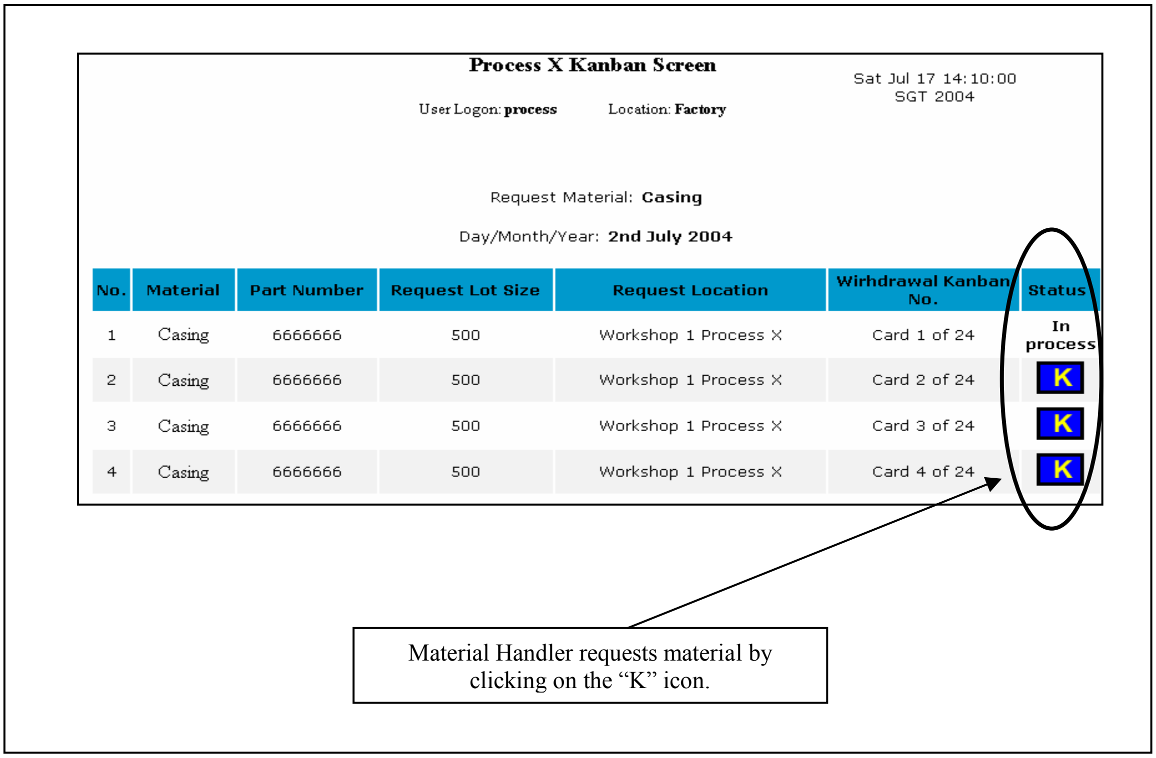


Figure 3.14 Process Kanban Flow Screen

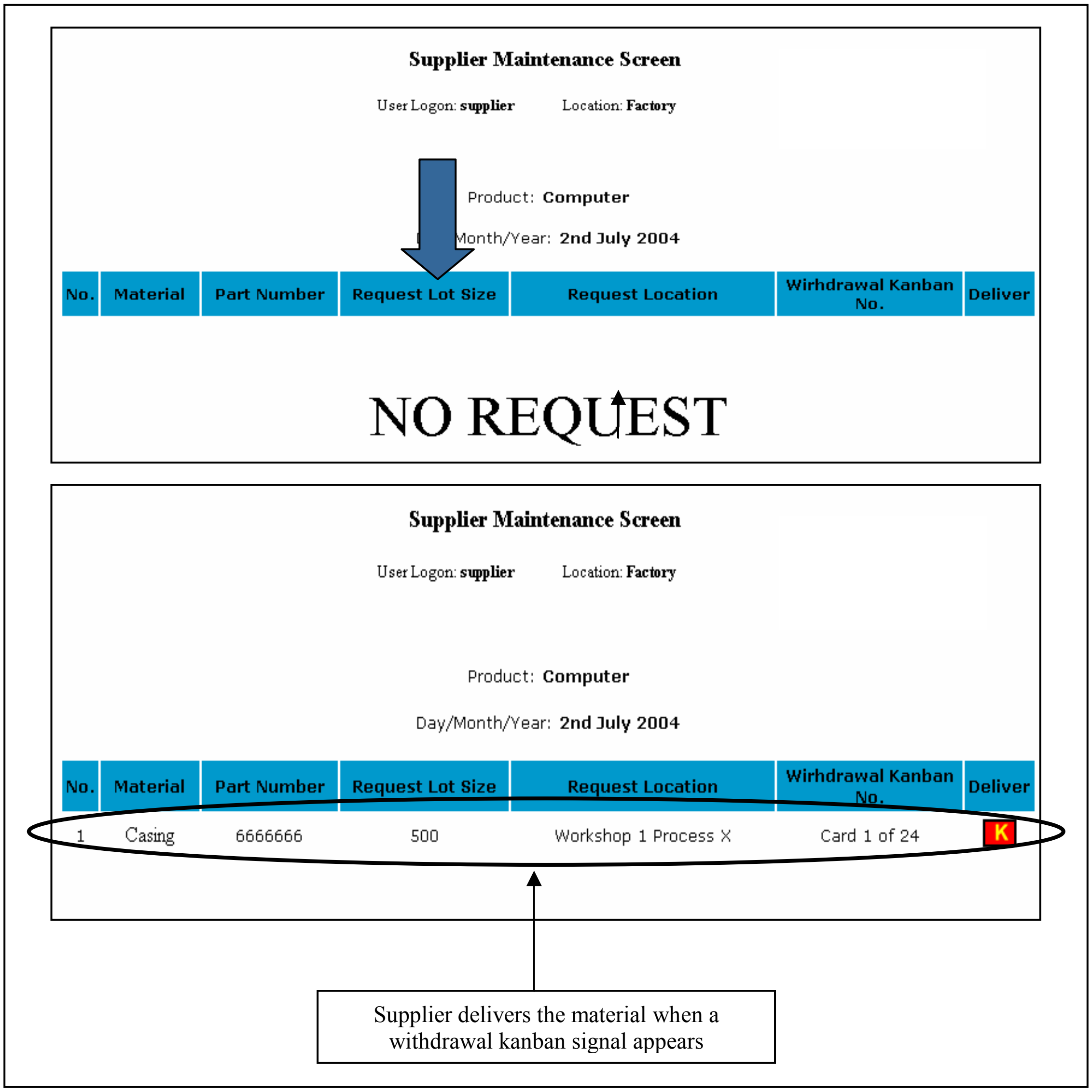


Figure 3.15 Supplier Kanban Flow Screen

3.7 Benefits of the Web-based Kanban System

The Web-based Kanban system primarily seeks to overcome most of the challenges faced by the traditional Kanban system mentioned in section 2.5. In addition, the proposed system also provides additional benefits to the dynamically changing market in today's manufacturing industry.

One of the major benefits provided by the Web-based system is flexibility. Today's market demand changes so rapidly such that manufacturing company will not only require a JIT management system but also one that can be easily implemented to adapt to these changes. The Web-based Kanban system will be able to offer rapid deployment of the Kanbans in this type of situation. Another major benefit of such a system is the relatively low cost involved in deploying and maintaining a Web-based system. The application can either be hosted within the manufacturing company's server or by a service provider. Since the Web-based application runs directly from the host server, it also minimizes the cost of maintenance and installation.

Other benefits of the Web-based Kanban system include the ability to integrate with existing company's database or information management system, such as the Manufacturing Resource Planning (MRP) or Enterprise Resource Planning (ERP) system. It provides a viable alternative for manufacturing companies with a material supply chain system that can complement its manufacturing environment that requires a high standard of quality and tight tolerances on its products. These products such as electronics or wafer components, are usually manufactured or assembled in a clean room environment and the Web-based Kanban system helps to minimize the contamination caused by the handling and movement of the traditional kanbans.

As more manufacturing plants move towards outsourcing or sub-contracting to external suppliers, the system will greatly reduce the lead time across the supply chain by enabling real-time collaboration between the customers and suppliers. The use of vendor-managed inventory (VMI), whereby the customer or an independent vendor is responsible for maintaining the supplier's inventory level, within the virtual enterprise arena has brought about tremendous benefits, such as inventory visibility across the company's supply chain that can readily respond to fluctuation in demand. The emergence of third-party logistics, whereby independent logistic providers are employed to handle the transition of materials or products between suppliers and customers, will also require a more efficient information flow and visibility system among the supply chain partners. The Web-based Kanban system will be a solution to provide a real-time link between these collaborating customers and the suppliers via the Internet. The result is a leaner manufacturing system and supply chain with less inventory but more responsive to market demands.

Chapter 4: Application of Web-based Kanban (A Case Study)

4.1 Company Background

MNC* is a company that specializes in the manufacturing and assembly of hard disk drives. MNC's disk drive products within the storage industry range from price-sensitive personal computer desktop market to high-capacity and performance business workstations. MNC attributed much of its success to its sound business and manufacturing strategy, coupled with technical and technological competencies to address the rapidly growing storage needs of the world evolving at Internet speed.

MNC has several assembly plants located across the Asia Pacific region and they are connected by a comprehensive supply chain network. The company's strong emphasis in building a "lean" manufacturing and supply chain system has prompted the adoption of several innovative projects to help the company to achieve this vision. "Lean" is a philosophy that recognizes waste as the primary driver of cycle time and employs tools and techniques to continually to drive out the waste. MNC adopted the JIT Kanban pull system as one of the tools used in lean manufacturing to eliminate waste. This system also helps the company to achieve its goal as a world class manufacturing system since it helps to optimize and balance manufacturing processes through the linkage of cycle time, throughput and replenishment proximity.

* MNC refers to the multinational company where the case study in this thesis is being carried out. The real name of the company is not revealed for confidentiality

In order to maximize the potential benefits of JIT using the traditional Kanban system, MNC in Singapore introduces a simple e-Kanban system four years ago. This simple e-Kanban system uses the Intranet to replace the traditional system of kanbans to request material between assembly and material supply processes. Nevertheless, a study and analysis of the e-Kanban system reveals that it operates only as a simple visual interface link that could not meet the growing demand of a highly dynamic manufacturing environment in MNC.

4.2 Web-based Kanban System Project Plan

With the support of several key management stake holders within MNC, a detailed study of the current e-Kanban system was conducted. The inventory holding of the factory was collected and analyzed. Figure 4.1, 4.2, 4.3 & 4.3 shows the inventory trend of four major components of a hard disk drive product.

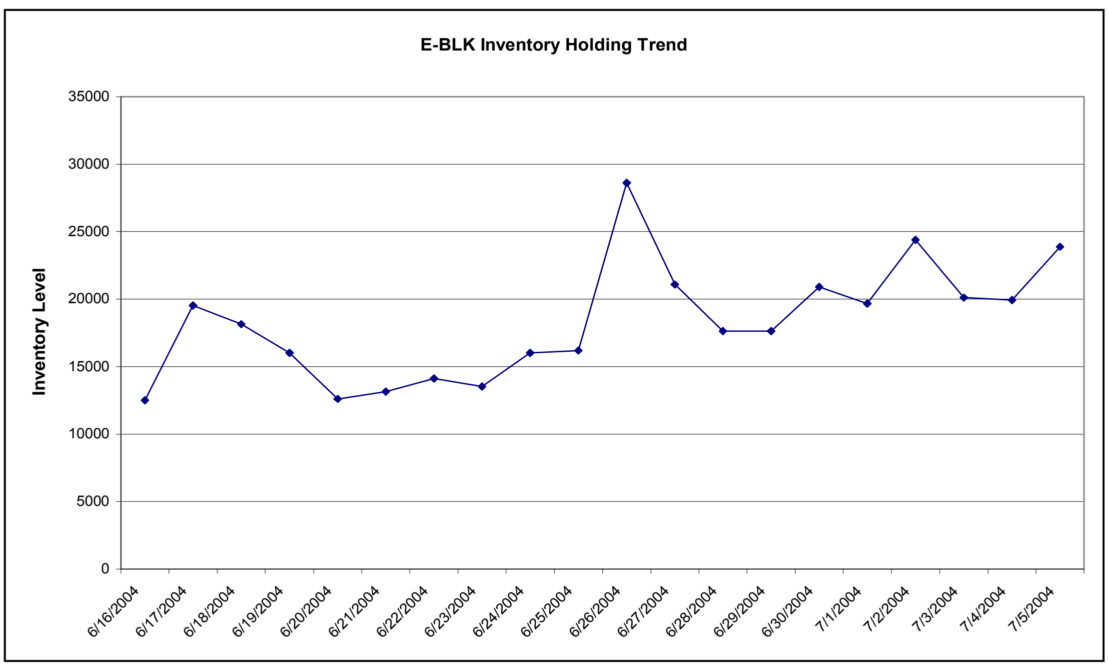


Figure 4.1 E-BLK Inventory Holding Trend

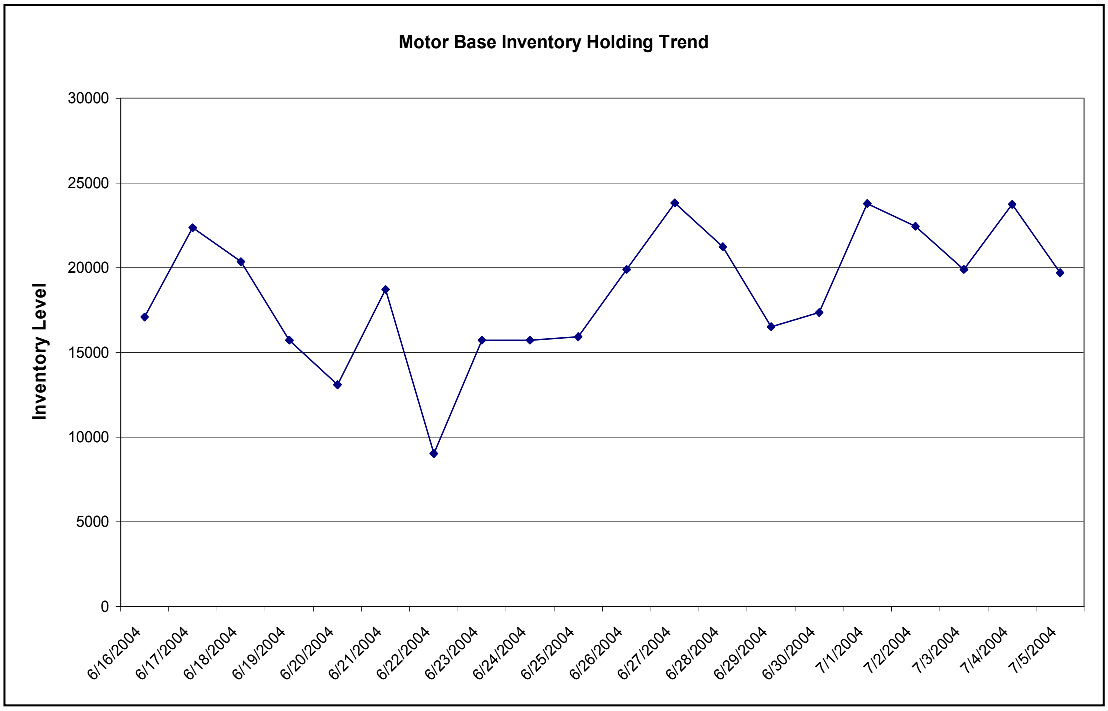


Figure 4.2 Integrated Motor Base Inventory Holding Trend

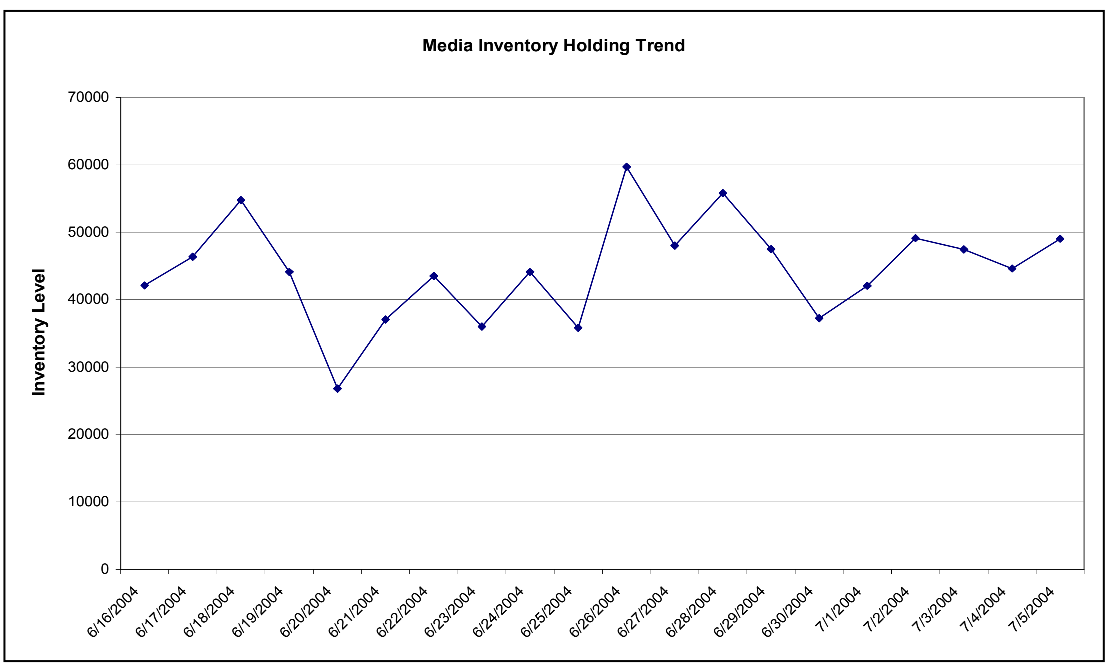


Figure 4.3 Media Inventory Holding Trend

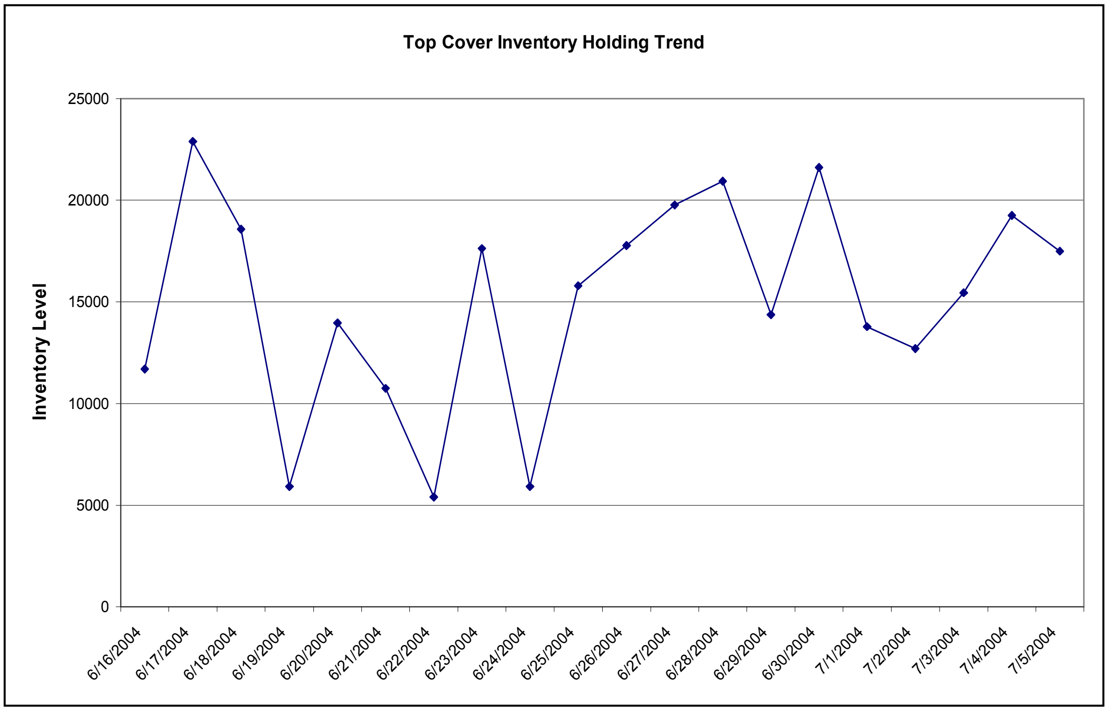


Figure 4.4 Top Cover Inventory Holding Trend

The inventory trend of the four major components revealed two main characteristics:

1. Large variation of inventory holding
2. Relatively high inventory holding periodically

A cause and effect diagram as shown in Figure 4.5 is constructed to determine the root cause of the inventory holding trend observed within the components. Based on the cause and effects diagram, two main controllable factors in 'man' and 'methods' were identified as top priorities that need to be addressed:

1. Additional man/headcount deployed in non-value added activities to track the inventory of the e-Kanban system and perform manual changeover of materials on the system.
2. The constant adjustment of the material trigger quantity to control inventory level based on production schedule and special requirement products by customers

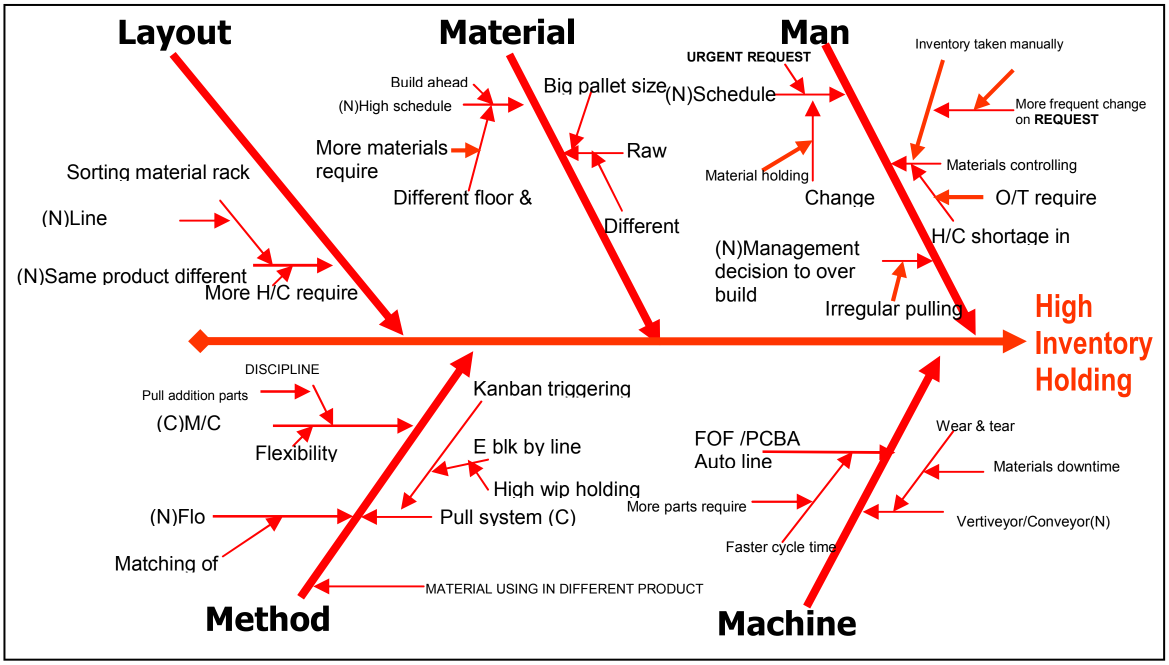


Figure 4.5 A Cause & Effect Diagram

This study revealed crucial areas in the current e-Kanban system that could be significantly improved to further optimize its inventory and WIP levels and bring about the elimination of non value added activities and other cost savings benefits to MNC. The major proposed changes in enhancing MNC's current e-Kanban system includes the introduction of several key features and functions within the software program, and the redesign of some material and workflow management in the manufacturing and production department.

A new enhanced Web-based Kanban system, officially named as i-Kanban (Intelligent-Kanban), was being worked out as an alternative solution to the challenges and problems posed by the current e-Kanban system. The i-Kanban employs the use of the four main Web-based Kanban modules mentioned in Section 3. As the current e-Kanban system is found to contain only the simple Kanban flow module, a systematic approach was developed to integrate the other three remaining main modules into the system. This contains a set of pre-defined rules that have the ability to make automatic adjustments to the kanbans dynamically based on real-time production schedule. The i-Kanban performs this functional role by first ensuring that the user activated the material part per assembly lines based on the daily requirements. The system was then designed to automatically carry out a check on the number of material parts activated and aggregate the required quantity before sending the request signal to the suppliers. Part of this methodology was developed using the Flexible Kanban System (FKS) proposed by Gupta, Al-Turki and Perry (1999) (mentioned in Section 2.4.4).

The inventory tracking module was built into the i-Kanban system to monitor the inventory level of the factory. This allows the production planner to predetermine the amount of material in the factory and prepare the appropriate schedule to load into daily production. This function also allows the user to make material part changeover easily without the need to carry out physical stock taking of the required material.

The resource maintenance module in the i-Kanban system allows the user to set the parameters for the computation of the kanban lot size. Besides the four main Web-based Kanban modules, i-Kanban also incorporates several customized modules for adaptation to MNC's assembly and material handling processes, such as date and time stamping of material flow between processes and periodic updating and interfacing with the BOM database that is kept in the oracle system.

Prior to the i-Kanban project approval, a cost and benefit analysis was carried out to justify the implementation of the project. Concurrently, an i-Kanban prototype was also being developed to demonstrate the feasibility of the proposed project. The two main projected cost and head count savings are:

- $100,000 reduction in inventory holding cost per product annually
- Headcount savings of 1 operator per assembly location

The proposed i-Kanban is also expected to minimize and eliminate the accumulation of obsolete materials parts. It will provide greater flexibility and adaptability in the management of material flow and material supply across the assembly lines.

Upon the successful approval of the project implementation, both the supply chain and IT team were roped in to facilitate the actual development and implementation of the new i-Kanban system. The software design specifications and requirements were worked out and MNC's IT team was responsible for the design and development of the i-Kanban software package as one of the project deliverables. The supply chain team helped to manage the coordination and preparation of other parties involved such as the production team and third party logistics provider. A Gantt chart showing the project timeline is given in Figure 4.6.

i-Kanban Project Gantt Chart

			May					June				July			
Task	Duration	Remarks	26/4	3/5	10/5	17/5	24/5	31/5	7/6	14/6	21/6	28/6	5/7	12/7	19/7
Requirements Study	2 weeks	IT Team													
Design	3 weeks	IT Team													
Development	4 weeks	IT Team													
3rd Party Test	5 days	Production													
User Acceptance Test	3 days	Production													
Training	2 days	Production													
Production Setup	2 days	Production													
Production - Cut over	1 day	Production													
Evaluation	2 weeks														

Figure 4.6 i-Kanban Project Gantt Chart

4.3 Implementation Issues

A few discussions between the IT and production team were conducted during the requirements study phase to fine-tune the system. Several production issues were brought out by the production team and minor changes had to be made to ensure that key assembly operations would not be affected during i-Kanban production cut over in the later stage. The IT team subsequently provided the business/software requirements specification entailing the detailed description of the various features required in the new i-Kanban software after the requirements study.

After the initial completion of the i-Kanban development, some end users from the production team were asked to perform a third party test. The test yielded several positive feedbacks as well as standard operating procedures that the users needed to adhere. A number of programming bugs and errors were fixed during this stage. Training for the material handlers was conducted immediately after the user acceptance test. Some minor problems, such as the inability of the users to comprehend the i-Kanban training materials provided, began to surface. The training materials were subsequently redesigned and practical hands-on training was conducted to give the material handlers opportunity to carry out a simulation trial run using a test prototype provided by the IT team.

The production setup phase of the project involved the preparation of the production team to move into i-Kanban implementation. Material staging racks were replenished to the required quantities as specified by the kanban lot size calculation. As the implementation was only carried out on a single product family initially, material part numbers had to be retrieved from the BOM by the i-Kanban users into the product assembly locations within the system. The system moderator had to enter the required parameters, such as replenishment lead time and Kanban container size in the i-Kanban setup. Material handlers were briefed by the supervisors about the expected changes and the inventory transfer procedure from current e-Kanban to i-Kanban system.

The start of production cut over took place during a change of shift in the production teams. The start of the implementation revealed some resistance by the material handlers to follow the standard operational procedures laid down earlier during the briefing. In addition, some did not see the need to change the way they had been handling the materials using the e-Kanban system. The supervisors were subsequently called in to ensure strict adherence of the material handlers to the procedures of material movement between processes.

4.4 Implementation Results and Evaluation

During the first day of the start of i-Kanban implementation, it was recorded that there was a slight increase in the quantity of materials being brought into the factory using the i-Kanban 'pull' system. This is inconsistent with the expected drop in inventory level during our project proposal analysis. The parameters that were input into the system during the i-Kanban setup were immediately compared and verified. A comparison between the actual supplier's replenishment lead times with the parameter settings revealed some discrepancies. A verification check on the actual service quality, in terms of lead time required to replenish material to the factory, of the supplier's delivery system showed that there were significant improvements and the replenishment lead time settings had to be consequently reduced. Moreover, it was realized that due to the dynamic response of the i-Kanban system to production schedule changes, the safety buffer stock level could also be further minimized. Subsequently, the resetting of these critical parameters immediately on the first day of implementation, when production team changed shifts, led to the expected result according to the analysis during project proposal.

Data collection for the project implementation was carried out consecutively for two weeks and an evaluation was carried out to compare with past performance indices. In order to monitor the performance of the i-Kanban system in regulating the quantity of materials being brought into the factory by the suppliers, a daily inventory report for a single product line at the factory stock receiving area was collected and analyzed. Figures 4.7, 4.8, 4.9 & 4.10 show the inventory holding trend of four major components that are collected over a period of one month.

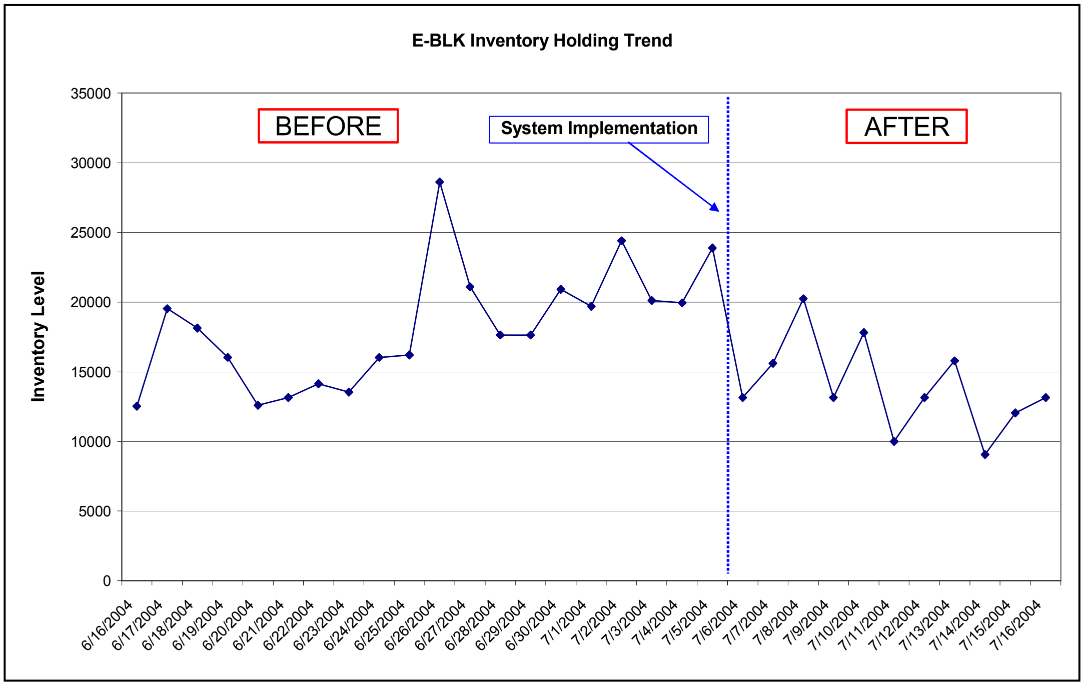


Figure 4.7 E-BLK Inventory Holding Trend after Implementation

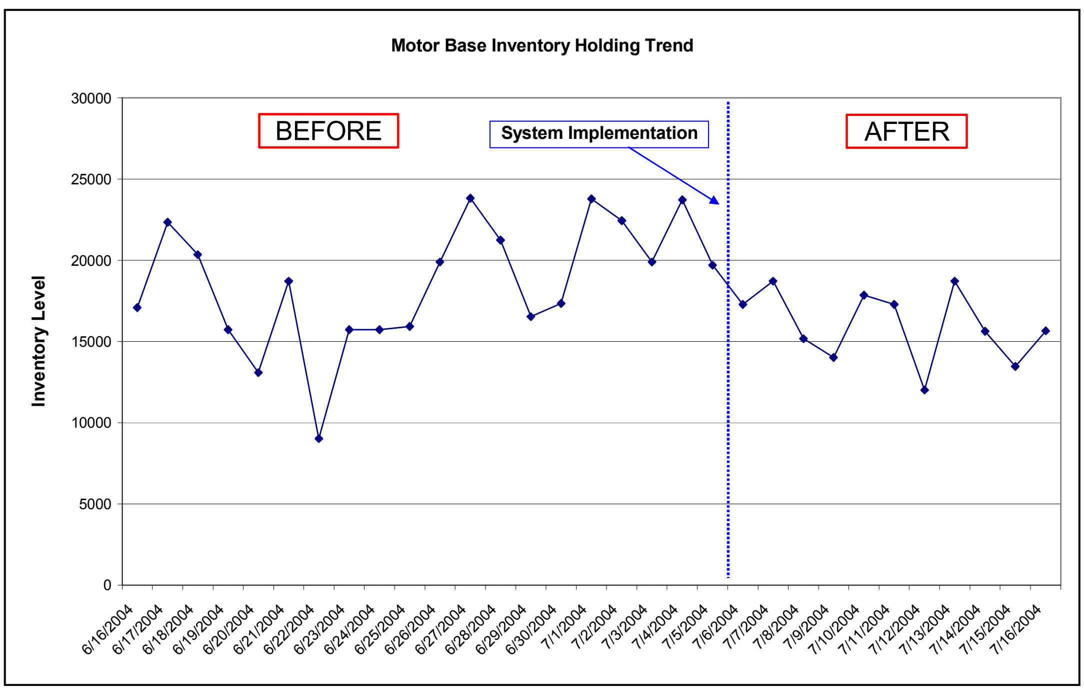


Figure 4.8 Integrated Motor-Base Inventory Holding Trend after Implementation

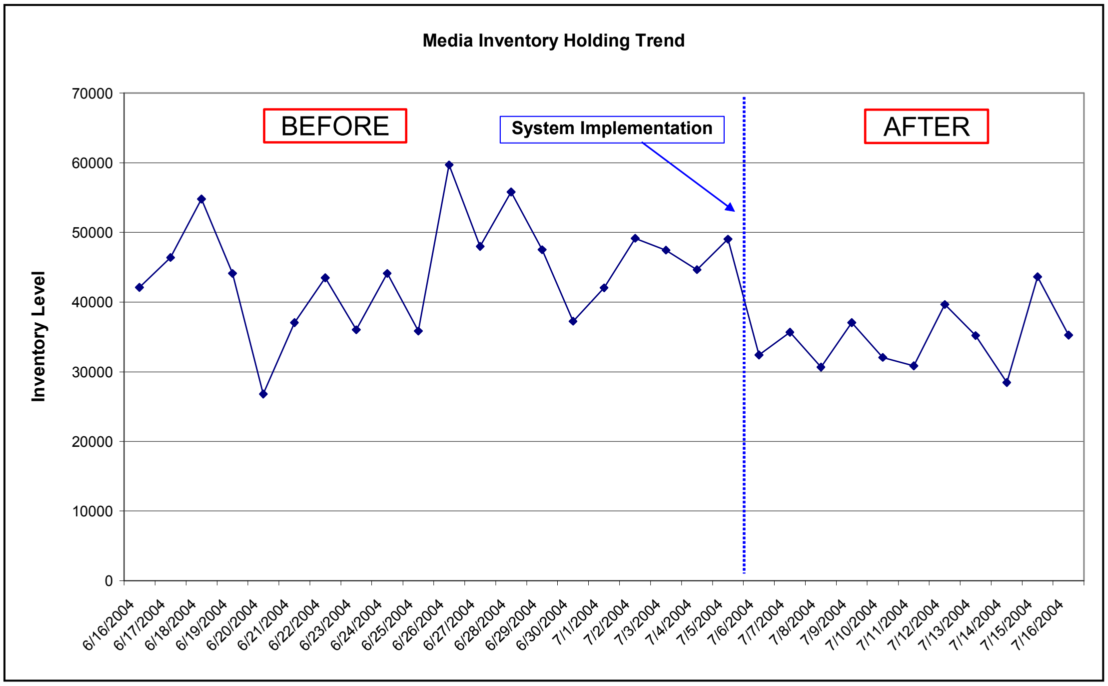


Figure 4.9 Media Inventory Holding Trend after Implementation

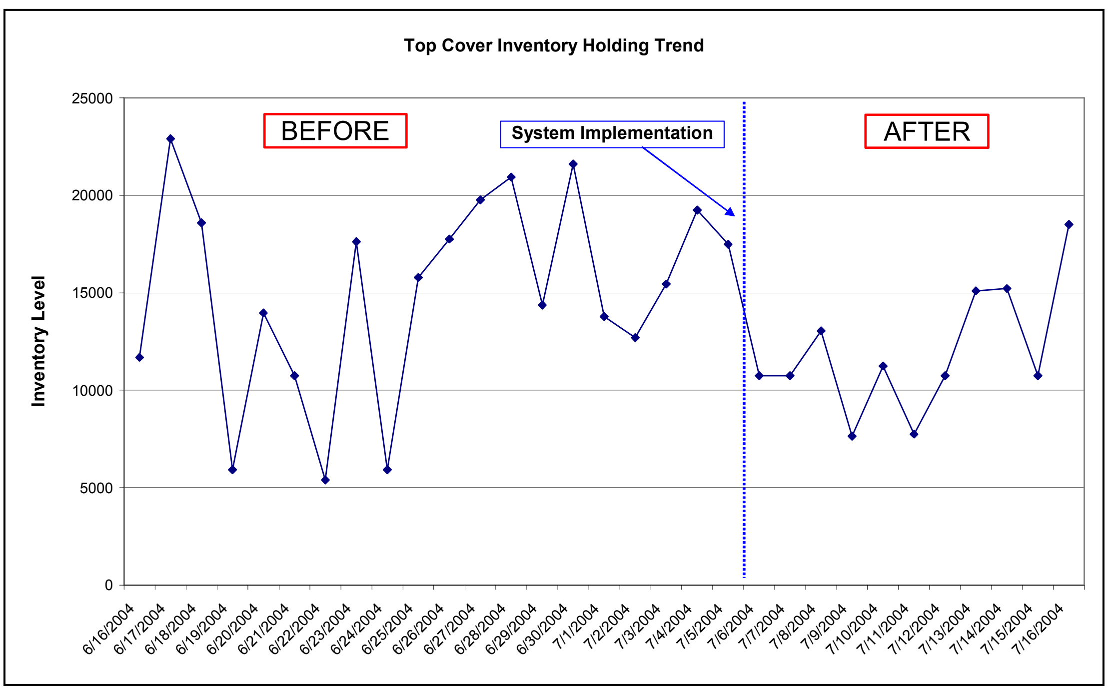


Figure 4.10 Top Cover Inventory Holding Trend after Implementation

Based on the inventory holding trend of the four major components, it was observed that there was a gradual drop in inventory after the i-Kanban system implementation. The dynamic response of the i-Kanban system to changes in production schedule also resulted in a stability of the daily inventory holding level after implementation, compared to large fluctuations in the pre-implementation stage whereby inventory can be inconsistently high at times.

The average daily inventory holding was also computed for the period before and after implementation. Figure 4.11 shows the calculated percentage reduction of inventory holding for the four major components.

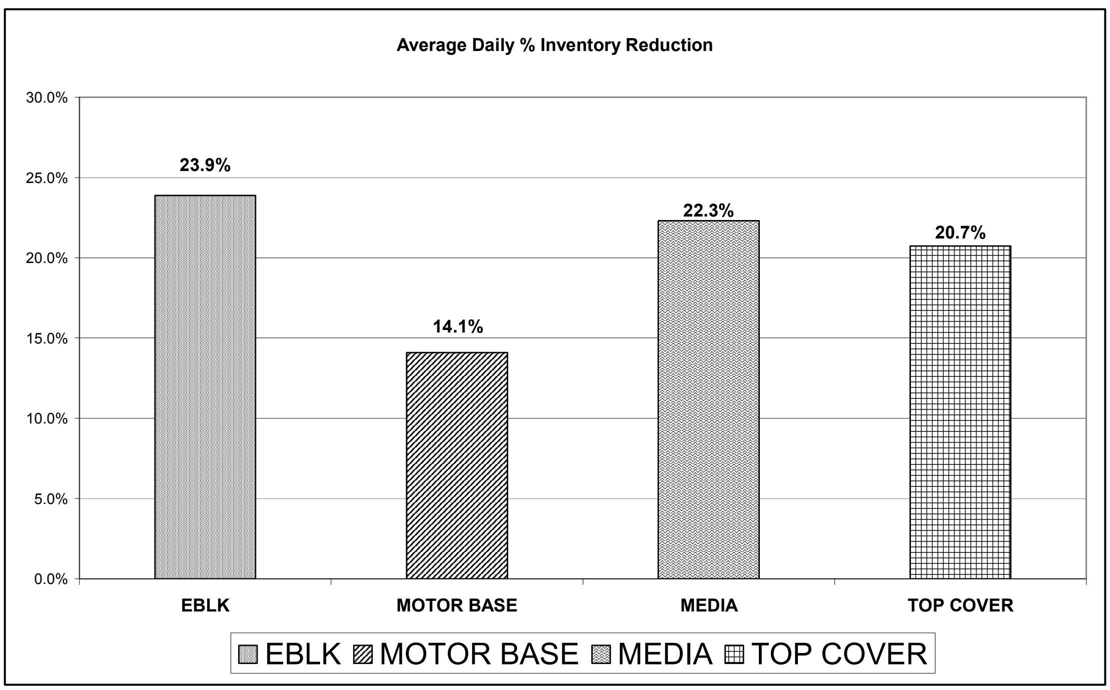


Figure 4.11 Percentage Reduction of Inventory Holding for 4 components

Figure 4.6 shows that there is a significant percentage reduction in the inventory holding level across the four major components. It is evident that the deployment of the i-Kanban system has been able to effectively supply the correct quantity of materials and at the right time without causing too much material stock out. The improvements and benefits of the new i-Kanban system are summarized in Table 4.1.

Table 4.1 Summary of Improvements and Benefits

Improvements/Benefits	Descriptions
Inventory Reduction	Inventory holding of all raw materials are reduced by approximately 20% in the factory
Elimination of non value added activities and head count savings	Head counts initially used in non value added activities such as regular stock taking and materials planning are reduced or deployed to other areas
Reduction of obsolete high-cost materials	Obsolete high-cost materials are reduced significantly in the factory
Reduction of replenishment lead time	Replenishment lead times are reduced by approximately 30%

Chapter 5: Conclusion & Recommendations

5.1 Conclusion

Advancement in the Internet/Web-based application has provided tremendous benefits and solutions to many global manufacturing industries. The current trend towards JIT manufacturing system in the dynamic product market demand has also opened up new opportunities for the JIT Kanban system to be integrated with Web-based technology. This research project has provided the manufacturing industries with a proposed Web-based Kanban system and the design methodology using the currently available Web-based technology platform. As observed in the case study, the notion of a "one size fits all" model or system will no longer be valid in today's context. Therefore the adoption of a Web-based Kanban system, which allows the company to further customize the application to suit its manufacturing operations, will serve as a competitive advantage. The recent rapid development in Web-based application solutions and development platform will further offer a company wide choices in deploying the Web-based Kanban software application within their manufacturing system to integrate with its own information technology.

The case study on the successful adoption and implementation of the Web-based Kanban system in MNC has served to justify several expected benefits and cost savings that the proposed system seeks to bring. The ability of the proposed Web-based Kanban system to integrate with the company's manufacturing system has proven the feasibility deploying such a system within a dynamic manufacturing environment. With the increased desire of companies to be recognized as a world class manufacturer, the proposed Web-based

Kanban system will prove to be useful for companies that are keen to bring their manufacturing technology to the next level of advancement and reap the associated benefits.

5.2 Recommendations for Future Research

Based on the case study and evaluation of the implementation results carried out within the company, the following are some possible areas for future research on the related topic:

- The use of Artificial Intelligence (AI) techniques in manufacturing to determine parameter settings, such as replenishment lead times. This allows the computations on the number of kanbans to be optimized according to changes in the manufacturing environment.
- Development of a systematic management workflow and material supply chain system in a manufacturing environment to complement the features of the Web-based Kanban system.

References:

[1] Marc J. Schniederjans, 1993, *Topics in Just-In-Time management* (Allyn & Bacon, Simon & Schuster Inc)

[2] A.Hallihan, P.Sackett, G.M.Williams, 1997, JIT manufacturing: The evolution to an implementation model founded in current practice. *International Journal of Production Research*, 35(4), 901-920.

[3] Japan Management Association, David J. Lu, 1985, *Kanban, Just-in-time At Toyota*. (Productivity Press Cambridge)

[4] Yasuhiro Monden, 1998, *Toyota Production System, An Integrated Approach to Just-In-Time* (Engineering and Management Press)

[5] Chris Voss, David Clutterbuck, 1989, *Just-In-Time: A global status report* (IFS Ltd, Springer-Verlag)

[6] Shari L.S. Worthington, Walt Boyes, 2002, *e-Business in manufacturing: Putting the Internet to work in the industrial enterprise* (ISA-The Instrumentation, Systems, and Automation Society)

[7] T.C.E. Cheng, S. Podolsky, 1996, *Just-in-Tine Manufacturing: An Introduction,* (Chapman & Hall)

[8] Paul M. Swamidass, Gregory P. White, 2000, *Innovations in Competitive Manufacturing: Just-in-time Manufacturing* (Kluwer Academic Publishers)

[9] Arnaldo Hernandez, 1989, *Just in Time Manufacturing: A Practical Approach* (Prentice Hall, Inc.)

[10] Harold J. Steudel, Paul Desruelle, 1992, *Manufacturing in the Nineties: How to be a Mean, Lean, World-Class Competitor* (Van Nostrand Reinhold)

[11] Alan Harrison, 1992, *Just-In-Time Manufacturing in Perspective* (Prentice Hall International (UK) Ltd)

[12] Jin H. Im, Richard J. Schonberger, 1988, The Pull of Kanban. *Production and Inventory Management Journal*, 4, 54-58.

[13] Romeo A. Esparrago 1988, Kanban. *Production and Inventory Management Journal*, 4, 6-10

[14] Yash P. Gupta, Mahesh Gupta, 1989, A System Dynamics Model of a JIT-Kanban System. *Engineering Cost and Production Economics*, 18, 117-130.

[15] Chun-Che Huang, Andrew Kusiak, 1996, Overview of Kanban Systems. *International Journal of Computer Integrated Manufacturing*, 9(3), 169-189

[16] T.M. Chang, Y.Yih, 1991, Determining the Number of Kanbans and Lotsizes in a Generic Kanban System: A Simulated Annealing Approach, *International Journal of Production Research,* 32(8)

[17] John D. Hall, Royce O. Bowden, Richard S. Grant, William H. Hardley, 1998, An Optimizer for Kanban Sizing Problem: A Spreadsheet Approach for Whirlpool Corporation, *Production and Inventory Management Journal,* 39(1), 17-23

[18] Ina S. Markham, Richard G. Mathieu, Barry A. Wray, 2000, Kanban Setting Through Artificial Intelligence: A Comparative Study of Neural Networks and Decision Trees, *Integrated System Manufacturing,* 11(4), 239-246

[19] John M. Gross, Kenneth R. Mclnnis, 2003, *Kanban Made Simple: demystifying and applying Toyota's legendary manufacturing process* (New York Amacom)

[20] Richard J. Schonberger, 1983, Applications of Single-Card and Dual-Card Kanban, *Interfaces*, 13(4), 56-67

[21] Mark L. Spearman, David L. Woodruff, Wallace J. Hopp, 1990, CONWIP: A Pull Alternative to Kanban, *International Journal of Production Research*, 28(5), 879-894

[22] T.M. Chang, Y. Yih, 1994, Generic Kanban System for dynamic environments, *International Journal of Production Research*, 32(4), 889-902

[23] Surendra M. Gupta, Yousef A.Y. Al-Turki, Ronald F. Perry, 1999, Flexible Kanban System, *International Journal of Operations & Production Management,* 19(10), 1065-1093

[24] Ansari, Batoul Modarress, 1995, Wireless Kanban, *Production and Inventory Management Journal*, 36(1), 60-64

[25] Cullen, Thomas James, 2002, Toyota speeds parts delivery with e-Kanban. *Automotive News*, 77(6006), 22B

[26] Hunt Corporation, 2003, Innovative e-Kanban Ups Inventory Performance & Speeds Delivery, *Inventory Management Report*, 3(3)

[27] Anthony Grace, 2000, Web Design Fundamentals, *Course work submitted in partial fulfillment of the requirements of the degree B.Sc. Applied Computing / B.Sc. Commercial Software Development (http://www.peoi.org/Courses/Coursesen/web/foreword.html)*

[28] Hongbo Lan, Yucheng Ding, Hun Hong, Hailiang, Bingheng Lu, 2003, A Web-based manufacturing Service System for Rapid Product Development, *Computers in Industry*, 54, 51-67

[29] Varsha Apte, Tony Hansen, Paul Reeser, 2003, Performance Comparison of Dynamic Web Platforms, *Computer Communications,* 26, 888-898

[30] Zend Technologies Whitepaper, 2001, Expanding the Commercial Value of PHP to the Enterprise, *(http://www.intranetjournal.com/articles/200105/pwp_05_24_01a.html)*

[31] Jason E. Sweat, 2001, Using PHP to Develop Three-Tier Architecture Applications – Part 1, Zend Technologies, (*http://www.zend.com/zend/tut/tutsweatpart1.php*)

[32] Sean Hull, 2004, PHP and ASP .NET Go Head-to-Head, *Oracle Technology Network Articles, (http://otn.oracle.com/pub/articles/hull_asp.html)*

[33] Gladwin, Lee Copeland, 2001, Active Server Pages, *Computer World (Ebsco Publishing),* 35(12), 64

[34] Mark Gibbs, 2002, Getting Under the Hood of ASP, *Network World*, (http://www.nwfusion.com/columnists/2002/1125gearhead.html)

[35] Inderjeet Singh, Beth Stearns, Mark Johnson, Sun Microsystems Enterprise Team, 2002, Designing Enterprise Applications with J2EE Platform Second Edition, *Addison-Wesley*

[36] Pankaj Chowdhry, 1999, JSP will Win Hearts but Competition is Strong, *Business Source Premier (PC Week Labs)*, 16(31)